PB88-251145

Solid Waste Dilemma: An Agenda for Action
Appendices A-B-C

(U.S.) Environmental Protection Agency
Washington, DC

Sep 88

U.S. Department of Commerce
National Technical Information Service
NTIS

50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO. EPA/530-SW-88-054B

2.

3. PB88-251145

4. Title and Subtitle

Appendices A-B-C to the Background Document for the Solid Waste Dilemma an Agenda for Action Draft Report of the Municipal Solid Waste Task Force

5. Report Date August 1988

6.

7. Author(s) Office of Solid Waste

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

U.S. EPA
Office of Solid Waste
401 M Street,SW
Washington, DC 20460

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

These Appendices A-B-C supplement the Background Document for the Solid Waste Dilemma: An Agenda for Action. The Appendices include major waste stream components, other contributors to the waste and factors determining the true costs of solid waste management technologies

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement

RELEASE UNLIMITED

19. Security Class (This Report)

20. Security Class (This Page)

21. No. of Pages 432

22. Price

(See ANSI-Z39.18)

See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

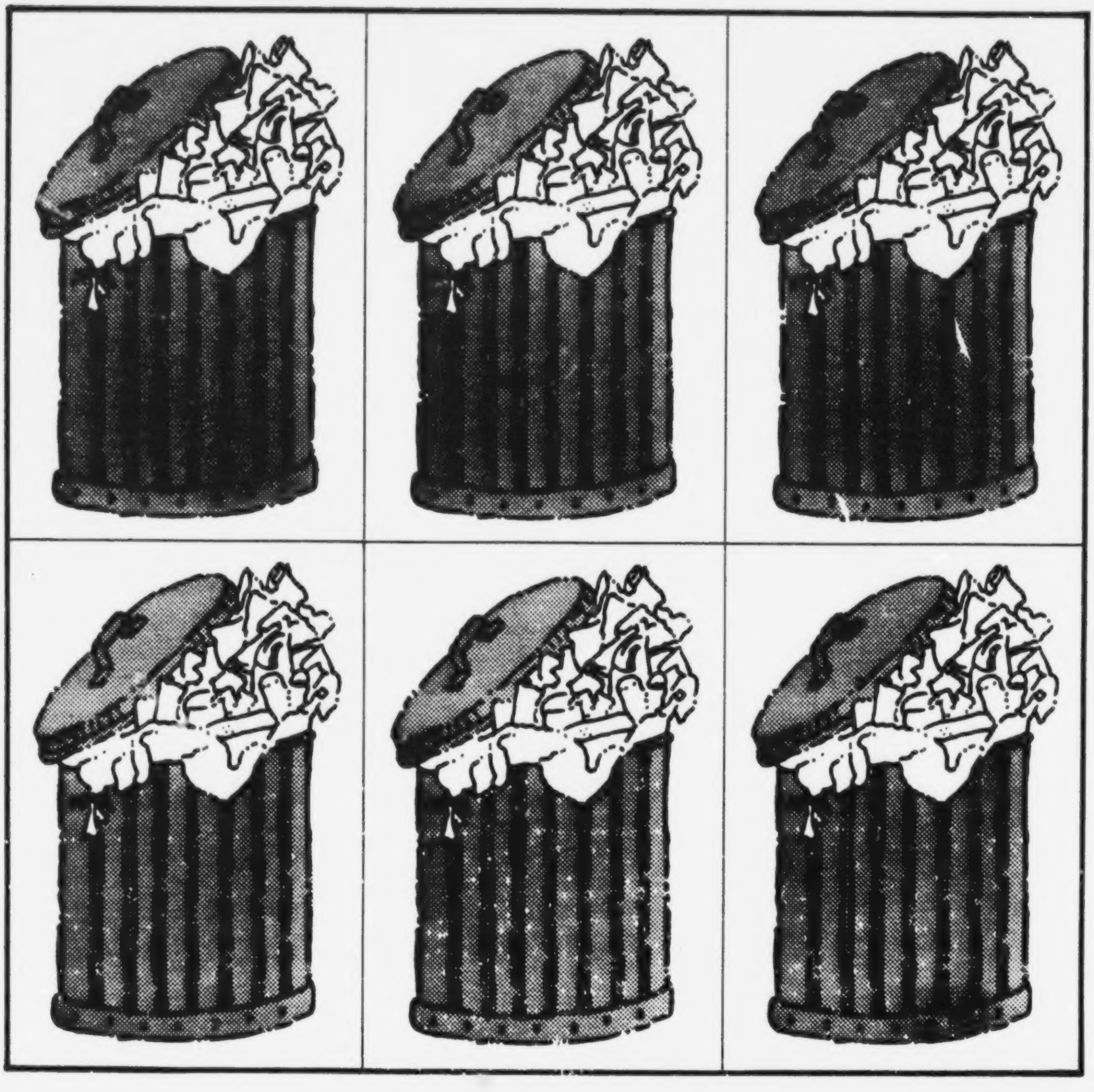
United States
Environmental Protection
Agency

Office of Solid Waste
September 1988
PB88-251145

EPA

The Solid Waste Dilemma: An Agenda for Action

Appendices A-B-C



Draft Report
of the Municipal Solid Waste Task Force
Office of Solid Waste
United States Environmental Protection Agency
September 1988

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

EPA/530-SW-88-054B

APPENDICES

A - B - C

LIST OF APPENDICES

A. MAJOR WASTE STREAM COMPONENTS

- A.A Paper
- A.B Glass
- A.C Plastic
- A.D Food and Yard Waste
- A.E Tires
- A.F Batteries
- A.G Metals and White Goods

B. OTHER CONTRIBUTORS TO THE WASTE STREAM

- B.A Combustion Ash
- B.B Demolition/Construction Waste
- B.C Automobiles
- B.D Sludge
- B.E Household Hazardous Wastes and Small Quantity Generators
- B.F Used Oil
- B.G Infectious Waste

C. FACTORS DETERMINING THE TRUE COSTS OF SOLID WASTE MANAGEMENT TECHNOLOGIES

TABLE OF CONTENTS

APPENDIX A

MAJOR WASTE STREAM COMPONENTS

Page

A. PAPER A.A-1
  1. Quantity and Sources of Paper in MSW A.A-1
  2. Waste Management Practices A.A-18
  3. Issue Identification A.A-49
  References A.A-53

B. GLASS A.B-1
  1. Quantities and Types of Glass Waste A.B-1
  2. Current Waste Management Practices A.B-21
  References A.B-50

C. PLASTIC A.C-1
  1. U.S. Production of Plastics A.C-2
  2. Waste Management of Plastics A.C-9
  3. Conclusion A.C-26
  References A.C-28

D. FOOD AND YARD WASTE A.D-1
  1. Quantity and Trends A.D-1
  2. Variations: Seasonal and Regional A.D-2
  3. Management Practices A.D-6
  4. Problems A.D-19
  References A.D-22

E. TIRES A.E-1
  1. Summary A.E-1
  2. Volume and Type of Waste A.E-1
  3. Current Practices A.E-2
  References A.E-14

F. BATTERIES A.F-1
1. Introduction A.F-1
2. Household Batteries A.F-1
3. Automobile Lead-Acid Batteries A.F-11
References A.F-21

G. METALS AND WHITE GOODS A.G-1
1. Introduction A.G-1
2. Waste Composition and Quantities A.G-1
3. Grades and Types of Scrap Metal A.G-4
4. Management Practices A.G-18
References A.G-42

LIST OF TABLES

APPENDIX A

Table		Page
A.A-1	Paper Consumption, Paper Products, and Total Discards into Municipal Solid Waste, 1960 to 2000	A.A-2
A.A-2	Principal Product Categories for Paper	A.A-6
A.A-3	Summary of Consumption, Diversions and Recovery, and Net Waste Discarded for Paper and Paper Products	A.A-7
A.A-4	Consumption of Recovered Paper in Domestic Paper and Paperboard Mills, 1986	A.A-12
A.A-5	Uses of Recovered Waste Paper, 1960 to 1986	A.A-14
A.A-6	Suitability of Principal Paper Grades for Recycling by Various Mill Types	A.A-30
A.A-7	Geographic Distribution of Mill Capacity for Wood Pulp and Waste Paper as Fibrous Raw Materials, 1988	A.A-34
A.A-8	Waste Paper Recovery, Consumption, and Trade	A.A-41
A.A-9	MSW Net Discards Composition/Energy Values	A.A-44
A.A-10	Sort Results: All Landfills	A.A-48
A.B-1	Glass Shipments	A.B-5
A.B-2	Glass Containers and Packaging Discarded into the Municipal Waste Stream, 1960 to 2000 (in millions of tons)	A.B-7
A.B-3	Glass Containers and Packaging Discarded into the Municipal Waste Stream, 1960 to 2000 (as percentage of total discards)	A.B-8
A.B-4	Environmental Benefits Derived from Substituting Secondary Materials for Virgin Resources	A.B-14
A.B-5	Specifications for Furnace-Ready Cullet	A.B-16

A.B-6 Recovery Rates for Aluminum, Paper, and Glass in Selected Countries (1985) A.B-25
A.B-7 1984 Comparison of Glass Collected for Recycling in European Countries Related to Availability of Sites and Glass Container Usage A.B-43
A.B-8 Proportion of Complete Bottles Reused in Japan A.B-46
A.B-9 Glass Recovery by Region in Japan A.B-47
A.B-10 Output of Bottles and Quantity of Cullet Used in Japan A.B-48
A.C-1 Plastic Consumption by Major Markets: 1985 A.C-7
A.C-2 Consumption of Major Feedstocks for Plastics in 1986 A.C-10
A.C-3 Plastics Disposed to the Municipal Waste Stream A.C-13
A.D-1 Estimated Average Seasonal Yard Waste Composition for Portland, Oregon A.D-4
A.D-2 Estimated Yard Waste in Waste Stream, by Area A.D-5
A.E-1 Proximate, Ultimate, and Metal Analysis of Bead- and Cord-Free Shredded Scrap Tires A.E-3
A.E-2 Trace Element Analyses of Scrap Tire Ash A.E-5
A.G-1 Metal Discards A.G-2
A.G-2 Separation of Metals A.G-2
A.G-3 Five Groups of Ferrous Scrap A.G-9
A.G-4 Grades of Nonferrous Scrap A.G-14
A.G-5 Melting Points A.G-21
A.G-6 Number of Establishments by Size of Firms-SIC Code 3314 Secondary Smelting and Refining of Nonferrous Metals A.G-25
A.G-7 Number of Establishments Dealing in Scrap and Waste Materials Throughout the United States--SIC Code 5093 A.G-26

A.G-8 Number of Establishments Dealing in Scrap and Waste Materials by Size and Type of Firm--SIC Code 5093 A.G-30

LIST OF FIGURES

APPENDIX A

Figure		Page
A.A-1	Recovery of Waste Paper for Paper Industry Utilization, Exports, and Other Uses, 1960 to 1986	A.A-15
A.B-1	Actual Glass Discarded into Municipal Waste Stream	A.B-2
A.C-1	Estimated Disposition of Plastics - 1985	A.C-12
A.F-1	Mercury Usage in U.S. Consumer Battery Production	A.F-6
A.F-2	Battery Shipments: 1960 - 1986	A.F-12
A.F-3	Battery Recycling Rates: 1960 - 1985	A.F-13
A.F-4	Number of Batteries Exiting the Recycling Chain	A.F-16
A.F-5	Battery Recycling Chain	A.F-17
A.F-6	Battery Recycling Rates and Lead Prices	A.F-18

TABLE OF CONTENTS

APPENDIX A

A. PAPER

Page

1. QUANTITY AND SOURCES OF PAPER IN MSW A.A-1
   a. Introduction A.A-1
   b. Historical Patterns and Trends of Paper Consumption A.A-4
   c. Grades and Uses of Waste Paper A.A-10
   d. Historical Trends of Paper Recovery A.A-11
   e. Regional Variations A.A-17

2. WASTE MANAGEMENT PRACTICES A.A-18
   a. The Versatility of Paper to Fit into Alternative Waste Management A.A-18
   b. Source Reduction A.A-20
   c. Recycling and Reuse A.A-23
   d. Economics and Markets A.A-32
   e. Nonmarket Factors A.A-39
   f. Paper Recycling Practices in Other Nations A.A-40
   g. Incineration and Energy Recovery A.A-42
   h. Landfilling A.A-46
   i. Other Considerations A.A-48

3. ISSUE IDENTIFICATION A.A-49
   a. Capacity as It Relates to Solid Waste Management Options A.A-49
   b. Fiber as a Material Resource Base A.A-51
   c. Summary of Issues of Significance and Areas of Opportunity to Resolve A.A-52

REFERENCES A.A-53

APPENDIX A
MAJOR WASTE STREAM COMPONENTS

A. PAPER

1. QUANTITY AND SOURCES OF PAPER IN MSW[1]

a. Introduction

Paper and paperboard products constitute the largest single category of manufactured materials and products in municipal solid waste (MSW). From a quantity standpoint, paper products also exceed the combined impact of food and yard wastes, which are the next two largest categories of MSW that follow paper in tonnage disposed of in the United States.

In 1986, 50.1 million tons of paper products ended up in MSW to be disposed of by landfill or incineration, which is 35.6 percent by weight of MSW disposed of during that year. Paper requiring disposal has grown steadily in tonnage through the years (with declines apparent only in years of economic downturns). Projections to the year 2000 indicate the same trend given a "status quo" projection. The basic quantity data are presented in Table A.A-1 in 5-year intervals starting with 1960 and ending with 2000.

Since paper products are dominant as the principal component of MSW, some attention needs to be given to the opportunities to reduce the quantity of paper and its percentage of the waste stream, thereby reversing the historical trends. This reversal may now, in fact, be taking place through increased recovery for recycling.

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[1] Paper is used here in the generic sense and includes both paper and paperboard. (Outside the paper industry, paperboard is often called cardboard.)

TABLE A.A-1

PAPER CONSUMPTION, PAPER PRODUCTS, AND TOTAL DISCARDS* INTO MUNICIPAL SOLID WASTE, 1960 TO 2000

(In million short tons and percent)

Year	Total Paper Consumption** (million tons)	Paper Products in MSW (million tons)	Total MSW (million tons)	Paper as a Percent of MSW	Paper Disposed of as a Percent of Consumption
1960	38.5	24.5	81.7	30.0	63.6
1965	48.3	32.2	96.1	33.5	66.6
1970	56.0	36.5	112.5	32.4	65.2
1975	54.1	34.4	116.2	29.6	63.6
1980	67.1	42.0	129.2	32.5	62.6
1985	76.3	48.7	137.3	35.5	63.8
1986	79.8	50.1	140.8	35.6	62.6
1990	86.0	54.9	149.0	36.8	63.8
1995	96.0	60.2	158.9	37.9	62.7
2000	106.5	66.0	168.8	39.1	62.0

---

*Defined as disposal after materials recovery has taken place

**Adjusted for exports and imports. Also called "new supply" in the industry.

Note: The difference between total paper consumption and paper in MSW is accounted for by recovery for recycling and by diversion such as permanent storage, disposal in sewers, etc. (See Table A.A-3 for detail.)

Source: Franklin Associates, Ltd. Characterization of Municipal Solid Waste in the United States States, 1960 to 2000 (Update 1988); U.S. Environmental Protection Agency, March 20, 1988.

Consumption (new supply) 1960 to 1986 from the American Paper Institute; projections by Franklin Associates, Ltd.

The paper industry recognizes a number of major grade categories, which represent general end-use classifications for its products. (See Table A.A-2). Paper is produced at paper mills in the United States or elsewhere (e.g., Canada). It is then shipped to a converter (e.g., an envelope maker), which may or may not be the company that produced the paper originally. The converted paper is then put into service as a product that, after its useful life is ended, is discarded. Some of the discarded products are recovered for purposes of reuse and recycling. As shown in Table A.A-1, however, a high percentage of the annual consumption ends up in landfills or incinerators.

In the process of conversion, the paper scrap produced is recovered by the converter and sold for recycling.

In general, paper products by their nature and intent have a short useful life (e.g., newspapers, magazines, packaging, tissue, etc.). Other paper-based products have a long useful life, again because of their nature (e.g., hardbound books, maps, construction products, and the like).

About 9.5 percent of paper products end up being diverted from entry into MSW systems for various reasons such as permanent storage (books); discharge into wastewater treatment systems (toilet tissue); use in construction products, automobiles, etc.; burning in fireplaces, etc. The principal diversion from MSW that takes place, however, is the recovery of paper for recycling purposes. These numbers will be presented later, but the combined effect of diversion and recovery for recycling can be observed in Table A.A-1 as the difference between paper consumption and paper in MSW. In 1986, for example, 62.6 percent of paper consumed was handled in MSW management systems. It is this latter category of paper to which attention will be directed later in this appendix.

b. Historical Patterns and Trends of Paper Consumption

Trends in MSW generation show that paper is increasing as a percentage of MSW. Three interrelated factors influence the percentage figure, but two of them are independent of the paper component of MSW.

- First, paper consumption (and discards) "track" real GNP[2] rather closely, and thus economic activity. As a consequence, paper in MSW and the potential for increased recycling may fall above or below the trend line simply on the basis of economic activity.

- Second, the recovery of paper for recycling largely determines what remains for disposal. There is evidence that the recovery rates increased significantly in 1986 and again in 1987, which may signal a new trend not yet reflected in the data base. Both years were "boom" years in the paper industry for production and recycling.

- Third, the percentage of paper disposed of is measured against total MSW disposal, and any growth or decline in disposal tonnages of other MSW constituents may make paper rise or fall as a percentage of total MSW independent of the activity of paper consumption and recovery.

Historical patterns and trends in paper consumption by major paper category and by sources of discards are discussed in the following sections.

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[2] Real GNP is Gross National Product adjusted to remove inflation and restate the value in terms of a base year such as 1982.

(1) Consumption by Major Paper Category

The solid waste cycle starts with the discard of paper products. They become a part of MSW when there is no use for them and when they are not recovered for recycling. The beginning point, however, is the demand for (or consumption of) the basic products. A summary for 1986 was developed to illustrate paper consumption by more detailed categories than those shown in Table A.A-1. The 1986 data are displayed in seven product groups as shown in Table A.A-2.

The consumption of various products is given in Table A.A-3. (Consumption = domestic production + imports - exports. The term "new supply" is used interchangeably with consumption.)

As may be observed in Table A.A-3, more than half the consumption of paper and paperboard products is paper as newsprint, printing-writing papers, paper packaging, and tissue. Most of the products represented have relatively short useful lives and are discarded daily (or even in minutes or seconds). In total, paper constitutes 45.2 million tons, while paperboard is 32.6 million tons and construction paper is 2.0 million tons.

Recovery for recycling is a very significant category. As may be observed in Table A.A-3, total recovery of waste paper in the old newspaper and corrugated grades is high both in tonnage and percentage. The recovery value is expressed both as a percentage of the total consumption and as a percentage of postconsumer discards.[3]

---

[3] Postconsumer recovery is determined as follows: Consumption - converting industrial scrap = net consumption. Total recovery - converting industrial scrap = postconsumer recovery. Postconsumer recovery divided by gross waste discarded x 100 = percent of postconsumer discards.

TABLE A.A-2

PRINCIPAL PRODUCT CATEGORIES FOR PAPER

Category	Product Group	Principal Products
Paper	Newsprint	Newspapers
	Printing-writing papers	Books, magazines, commercial printing, office papers, forms, bond, cotton fiber, file folders, computer paper, envelopes, etc.
	Packaging and industrial	Sacks, bags, wrapping paper, shipping sacks, industrial papers, etc.
	Tissue	Toilet, facial, napkins, toweling, packaging, etc.
Paperboard	Containerboard	Corrugated boxes
	Boxboard and other paperboard	Cartons, plates, cups, tube, can and drum, milk cartons, pad backs, etc.
Construction	Construction*	Insulating board, pressed board, etc.

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*Not included in MSW estimates in source below.

Source: Franklin Associates, Ltd. Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988), U.S. Environmental Protection Agency, Office of Solid Waste, March 30, 1988.

TABLE A.A-3

SUMMARY OF CONSUMPTION, DIVERSIONS AND RECOVERY, AND NET WASTE DISCARDED FOR PAPER AND PAPER PRODUCTS, 1986

(In thousand short tons and percent)

Paper Category	Consumption	Converting Scrap	Diversion	Gross Waste Discarded	Total Recovery*	Post-consumer Waste Recovery	Net Waste Discarded	Total Recovery as a Percent of Consumption	Post-consumer Recovery a a Percent of Gross Discards
PAPER									
Newsprint	12,994	325	63	12,606	4,125	3,800	8,806	31.7	30.1
Printing-Writing Papers	21,989	2,618	1,347	18,024	4,806	2,188	15,836	21.9	21.1
Paper Packaging and Industrial Converting	5,076	254	289	4,533	514	260	4,273	10.1	5.7
Tissue	5,144	257	1,906	2,981	257	0	2,981	5.0	0.0
Total Paper	45,203	3,454	3,605	38,144	9,702	6,248	31,896	21.5	16.4
PAPERBOARD									
Containerboard (corrugated)	21,604	2,160	0	19,444	10,160	8,000	11,444	47.0	41.1
Boxboard and Other Paperboard	10,963	1,864	2,002	7,097	2,264	400	6,697	20.6	5.6
Total Paperboard	32,567	4,024	2,002	26,541	12,424	8,400	18,141	39.0	31.6
CONSTRUCTION PAPER	2,046	143	1,903	0	143	0	0	7.0	0.0
GRAND TOTALS	78,816	7,621	7,510	64,685	22,269	14,648	50,037	27.9	22.6
Percent of Total Consumption	100%	9.5%	9.4%	81.0%	27.9%	-	62.7%	-	-

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*Includes converting scrap.

Source: American Paper Institute (consumption); Franklin Associates, Ltd., Characterization of Municipal Solid Waste in the United States, 1960 to 2000, Working Papers, Part E.

Overall, the disposition of paper consumed in 1986 was 7.5 million tons diverted[4] (9.4 percent), 22.3 million tons recovered for recycling (27.9 percent), and 50.0 million tons disposed of (62.7 percent). The recovery percentage was up significantly over 1985 and had not been at 28 percent recovery since 1955. Paper recovery for recycling increased again in 1987, with the American Paper Institute, Inc., reporting recovery of 23.9 million tons and a 28.6 percent recovery rate.

Consumption of paper in 1987 was also a record 83.7 million tons and production was 76.2 million tons, also a record high. Both paper industry use of waste paper and exports of waste paper increased significantly in 1987.

(2) Major Sources of Paper Discards

The paper products shown in Table A.A-2 exhibit different patterns of use and discard. These patterns are relevant to the waste management practices that will be discussed later. Patterns of discards will be discussed as residential, commercial, and industrial sources; these are the categories commonly used in waste management. Published data are scarce on quantifying waste composition by detailed sources, so the discussion will not be quantified.

(3) Residential Sources

Homes are the primary source of discarded newspapers. Homes also produce large quantities of books, magazines, commercial printing (e.g., direct mail advertising), and other printing/writing papers. Tissue products discarded from homes include facial tissues, napkins, and towels. Homes also generate large quantities of packaging papers such as sacks, bags, and wrapping papers.

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[4] Diversion is paper products that go into permanent storage (e.g., books); disposed of in sewer systems (e.g., toilet paper); and used in a paper product not normally found in MSW (e.g., construction products).

In the paperboard category, residences are not a major source of containerboard (corrugated boxes). They do generate large quantities of boxboard, which includes paper plates and cups and packaging such as milk cartons, food containers, shoe boxes, and so forth.

(4) Commercial Sources

The commercial category is very broad. It includes retail stores, restaurants and fast food establishments, office buildings, hotels, airports, schools, hospitals, wholesalers, and other businesses.

Newspapers are discarded from commercial sources, but not in quantities as large as from residences. Some sites such as airports and hotels are, however, large generators of newspapers. Office buildings are the major generators of printing/writing papers, including computer printout, copier paper, forms, and other writing papers. Tissue grades such as towels and napkins are discarded from establishments that have food service or washroom facilities. Packaging papers like sacks and bags are generated at many commercial establishments, although they may be discarded elsewhere, such as in homes.

Many commercial establishments are major generators of corrugated boxes. This is especially true of retail stores, where packaged and other goods are received in corrugated boxes, then removed for display in the stores. Commercial establishments, especially fast-food outlets, also discard boxboard in the form of paper plates, cups, and boxes.

(5) Industrial Sources

Industrial process wastes (even if nonhazardous) are not included in the MSW estimates.[8] Industrial sources (primarily factories and assembly plants) do, however, discard paper wastes that are classified as MSW. Factories generally have offices, food service, and rest rooms that are generators of office papers, tissue products, and packaging. In addition, many of these establishments (e.g., automobile assembly plants) are major generators of corrugated containers, which are used to ship parts for assembly. Other paperboard discarded from industrial sources includes fiberboard drums and the tubes and cores that fabric is wrapped around.

c. Grades and Uses of Waste Paper

The American Paper Institute (API) reports annually on the recovery of waste paper for consumption in domestic mills and other uses. While there are many grades of waste paper, reports on consumption use the following five categories:

- Mixed papers: Unsorted mixed papers, usually from commercial sources; the lowest quality of recovered paper. Mixed papers are most commonly used to make recycled paperboard or for construction papers like roofing felt.

- Newspapers: Old newspapers recovered from residences or other sources; may also include overissue news from publishers. The largest domestic use of old newspapers is in making deinked newsprint. The second largest use is in recycled paperboard.

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[8] Franklin Associates, Ltd. Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988), U.S. Environmental Protection Agency, Office of Solid Waste, March 30, 1988.

- Corrugated: Old corrugated and solid-fiber containers, plus container plant cuttings. The largest domestic use for old corrugated is in recycled paperboard. It is also used in making the linerboard (kraft or recycled) and corrugating medium (semichemical or recycled) that are used in new corrugated containers.

- Pulp substitutes: High-quality, unprinted waste paper, usually cuttings and trimmings from conversion of paper into envelopes, books, bleached paper boxes, and so forth. Pulp substitutes are used in making printing/writing papers, tissue papers, recycled paperboard (where they usually form the white outer layer on boxes), and other uses.

- Deinking: High-quality, usually bleached paper that has printing on it; includes scrap from printing plants and some office wastes such as computer printout and copier paper. Deinking grades are primarily used in making tissue papers (e.g., towels and napkins). Some are used in making printing and writing papers.

Note that the API definitions include converting scrap that is differentiated from postconsumer waste paper in the data base referenced in Table A.A-3. Use of recycled paper in domestic paper and paperboard manufacture is illustrated in Table A.A-4.

d. Historical Trends of Paper Recovery

In addition to use in domestic papermaking, a significant amount of recovered waste paper is exported, and a relatively small amount goes to other uses. A small amount of waste paper

TABLE A.A-4

CONSUMPTION OF RECOVERED PAPER IN DOMESTIC PAPER AND PAPERBOARD MILLS, 1986

(In thousand short tons)

Product Category	Mixed Papers	News-papers	Corrugated	Pulp Substitutes	High-Grade Deinking	Total
PAPER						
Newsprint	-	1,364	-	1	-	1,365
Printing & Writing	-	-	4	910	342	1,257
Packaging & Industrial Converting	25	10	107	183	5	331
Tissue	97	191	197	655	1,049	2,189
Total Paper	122	1,566	308	1,749	1,396	5,142
PAPERBOARD						
Kraft, Bleached, & Unbleached	-	-	1,561	112	10	1,684
Semichemical	50	-	1,607	48	-	1,704
Recycled	1,525	1,293	4,931	796	162	8,706
Total Paperboard	1,575	1,293	8,099	956	172	12,094
CONSTRUCTION PAPER & BOARD	348	259	277	57	1	892
TOTAL PAPER INDUSTRY	2,045	3,118	8,634	2,761	1,570	18,128

Source: American Paper Institute, Inc. Paper, Paperboard, Wood Pulp Capacity, 1986-1989.

is imported. These trends are shown in Table A.A-5 and Figure A.A-1 and are discussed below.

As the table and figure illustrate, domestic waste paper utilization has increased steadily in tonnage except for recession years. The utilization rate (which is the ratio of recyclable paper consumption to total production of paper and paperboard) has also been increasing since 1984, having risen from 23.8 percent in 1984 and 1985 to 25.1 percent in 1987. Paper production has increased significantly since 1985. The increased utilization rate also reflects a greater investment on the part of the paper industry in mill capacity to recycle. Said another way, wood pulp declined as a percentage of raw materials for papermaking. Finally, the capacity to use waste paper will increase from 24.5 percent of total fiber in 1986 to 25.4 percent of total fiber in 1989.[6]

In the short term (6 to 18 months), recycling capacity can be expanded by the startup of older idle mills, by more intense use of existing capacity, and by the incremental addition of recycle capacity at existing mills. Over a longer time period, a new paper mill requires substantial planning, permitting, siting, construction, and startup time. This is true whether the mill is a virgin-fiber mill or a recycle-fiber mill. By the same token, recycle capacity is often idled more rapidly than virgin capacity because these mills--often older and smaller--become uneconomical faster and because they often are used to produce products more sensitive to economic ups and downs.

Exports of waste paper have become increasingly important since 1975. The corrugated container grade represented about 40 percent of waste paper exports in 1986. Exports of old

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[6] American Paper Institute, Inc. Paper, Paperboard, Wood Pulp Capacity, 1986-1989.

TABLE A.A-5

USES OF RECOVERED WASTE PAPER, 1960 TO 1986
(In thousands of tons)

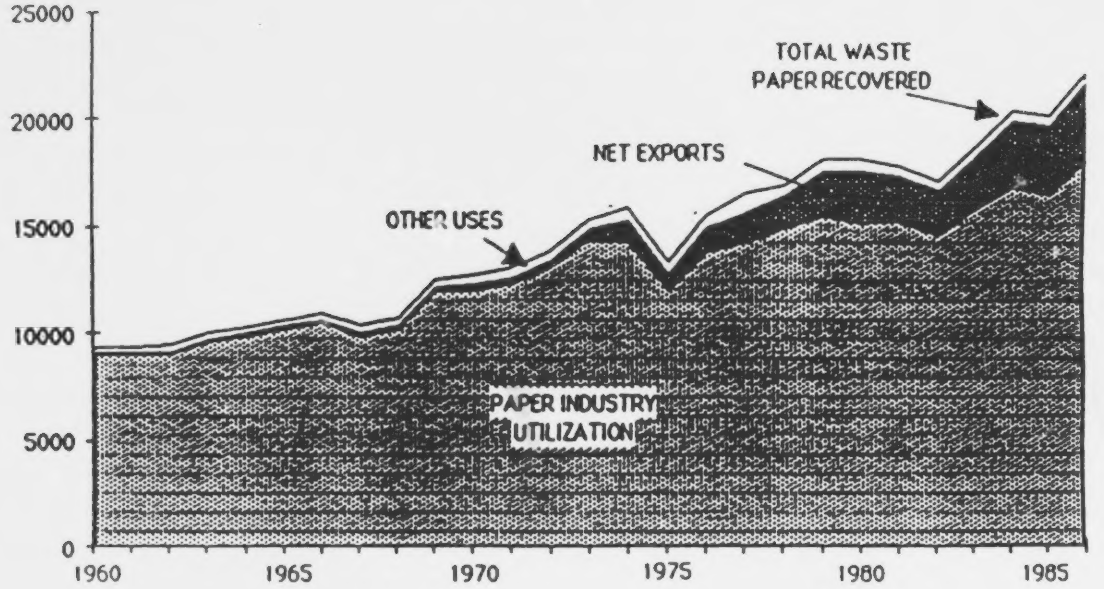
Year	Domestic Paper Industry	Net Exports*	Other Uses**	Total
1960	9,032	96	250	9,378
1965	10,231	184	250	10,665
1970	12,021	341	418	12,780
1975	11,983	789	535	13,307
1980	15,094	2,577	473	18,144
1985	16,550	3,199	478	20,227
1986	18,128	3,650	491	22,269
1987	19,113	4,295	504	23,912

---

*Exports minus imports.
**Molded pulp, cellulosic insulation, dunnage, etc.

Source: Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988). Report for U.S. EPA by Franklin Associates, Ltd. March 31, 1988, Engineering and Economic Analysis of Waste-to-Energy Systems. Report for U.S. EPA by the Ralph M. Parsons Co. June 1977, Figures are based on adjusting values from the references indicated to account for the moisture contents of "as generated" discards.

FIGURE A.A-1



Recovery of waste paper for paper industry utilization, exports, and other uses, 1960 to 1986 (in thousands of tons).

newspapers and mixed papers followed in importance, while relatively small amounts of the pulp substitute and high-grade deinking grades were exported. Countries importing large quantities of waste paper include Canada, Japan, Mexico, the Republic of Korea, and Taiwan.

A number of factors influence the trade of waste paper for export. The export of waste paper has more than doubled since 1982, from 2.1 million tons in 1982 to 4.4 million tons in 1987. Asian countries and Mexico require waste paper because they have virtually no forest resources. Also, their balance of trade with the United States is such that any purchases of raw materials help narrow a wide gap in trade. The relative value of the dollar to other currencies, especially the Japanese yen, stimulates exports too. Finally, sometimes ships take on waste paper simply because they need ballast to make a return trip (meaning that they do not have more valuable products to carry on their return trip). However, exports have accounted for almost all of the increased recovery rate of waste paper since the early 1970's until the last few years, when utilization rates began to rise in the U.S. paper industry.

Exports can be more volatile than domestic demand for waste paper. Precipitous declines in waste paper exports have occurred and no doubt will again.

Other uses of waste paper account for relatively small tonnages historically. These uses include cellulosic insulation, molded-pulp products (e.g., flower pots used by nurseries), and dunnage (packing material). Old newspapers are most commonly used for these purposes. There was a spurt of activity in cellulosic insulation production that peaked about 1977, but this has since declined. Other uses have not developed except for minor applications such as animal bedding and mulch. Some research has been done on the use of low grades of mixed papers and magazines as a bulking agent in sewage sludge composting.

e. Regional Variations

There are insufficient data to characterize paper consumption and discards on a regional basis. However, some useful general observations can be made. Variations in waste generation and disposal are determined more by population concentrations and population density than by any other factor. Also, whether an area is urban, suburban, or rural will have a great influence on the paper waste generation and disposal.

Metropolitan areas of 1 million or more people will experience greater per capita paper disposal than smaller population concentrations and rural areas. The two massive corridors of "Bos-Wash" (Boston to Washington, D.C.) and the greater Los Angeles area are even more pronounced in per capita generation. These areas have more industrial and commercial activity per capita, and more consumer purchases.

For example, analysis of newspaper discards indicates that per capita consumption of newsprint varies greatly. On a national average basis, the consumption of newsprint was about 108 pounds per person in 1986. However, in the Los Angeles area it is not uncommon to have consumption of double that average (i.e., over 200 pounds per person); in Boston, New York City, or New Jersey the same is true. In a rural area in the same regions, however, the generation rate for newspapers could be as low as 30 pounds per person per year. Also, the suburban areas are likely to generate the most per capita, and the central city could be at or below national average. Recovery for recycling will, of course, reduce disposal, but the point is still valid.

The same is true of old corrugated boxes and office papers. In areas where there is greater commercial activity, there will be greater generation of these two waste paper grades than in areas of less-dense population or rural areas. For example, assembly plants, warehouses, and large merchandising centers will generate old corrugated boxes. Large office complexes such as governmental and financial centers will also generate office papers in above-average rates.

These examples may serve to illustrate two points. First, waste generation is greater on a per capita basis in areas least able to provide landfill space, and the quantities disposed of will fill landfills more rapidly than other comparable areas with lower populations. Second, the "payoff" from recovery of any material such as newspapers is greater in a high-generation area and may have a much greater impact on landfill life. Also, the recovery potential per unit (e.g., home) participating is much higher in a suburban area as compared to a rural area, for example.

2. WASTE MANAGEMENT PRACTICES

a. The Versatility of Paper to Fit into Alternative Waste Management Systems

It is important to note that paper products are extremely versatile relative alternative solid waste management options. Paper is amenable to all four management options in the solid waste management hierarchy and, if littered, is degradable.

(1) Source Reduction

Like any material and product category, paper products may be made more efficiently to conserve materials and may contribute to the reduction of materials in any specific application. For example, package designers can change materials requirements, or a package may be made more functional than an alternative product. Also, a product could use an alternative ink or other applied material to eliminate a heavy metal such as lead or cadmium. Plastic coatings have been used very effectively to extend the uses of paper products into new markets. For example, many years ago, plastic-coated paperboard milk containers began displacing glass bottles. More recently, plastic milk bottles have come into widespread use, especially in the larger sizes. Neither type is reusable as the glass milk container was.

(2) Recyclability

Obviously paper, at 28 percent recovery, is very recyclable. Some of the grades disposed of in large quantities are the most readily recyclable--old newspapers, old corrugated boxes, and office papers. This alternative has great potential for expansion. Some paper products can be made more recyclable by changing an associated material such as inks, adhesives, or coatings. There are limits to recycling as well. Paper products that are contaminated with extraneous materials (e.g., food residues or associated materials such as coatings or adhesives) are not recyclable with current technology. Some types of paper are also very difficult or undesirable to attempt to recover such as tissue paper (e.g., towels), envelopes, telephone books, food packaging, and the like.

(3) Combustibility

As shown in a later section, paper has a high Btu value and burns without significant emissions or ash. Together, paper and plastics have boosted the average Btu value of MSW as both have grown relative to other components of MSW. The elimination of inks or other materials containing heavy metals may be particularly important where incineration is practiced. Paper may be burned for its energy content in conjunction with other components of MSW, or as a source-separated fuel that can be burned in conventional solid-fuel boilers.

(4) Degradability

Paper by its nature as a natural fiber is biodegradable and will degrade rapidly in the presence of water and oxygen (aerobic). Thus, littered paper usually disappears in a relatively short time. Landfills are generally designed to limit the intake of water, and the degradation process is anaerobic. Paper degrades very slowly in landfills, sometimes almost undetectable. The presence of plastic coatings, inks, food residues, and other associated materials may affect the rate of degradation. There is a lack of definitive data on degradation characteristics of paper in a controlled environment (i.e., landfill).

b. Source Reduction

By far the most difficult area to consider in paper products (or any other material or product group for that matter) is source reduction.

Product design and use have become more demanding over the past decade. The trend has been to make the product more functional and sometimes more durable. At the same time, the areas of growth have been in products whose useful life is shortened sometimes to minutes or seconds.

For example, fast-food service has grown remarkably with single-use packaging and napkins being a key part of that growth. Also, many products are more individualized today rather than being bulk (e.g., microwaveable meals and entrees).

There is no identifiable discipline in the system that requires taking product discard into account from the perspective of the solid waste management system. Thus, a product's "merits" may be that it is convenient and disposable for the user, not for the solid waste management system. An example is food packaging in a retail store. The package protects and may display the food, but it is immediately discarded when the food is consumed. In this context, source reduction is not a design consideration, because source reduction would not serve the marketplace.

Nondurable applications such as tissue products, printed materials, newspapers, magazines, and the like are similar examples. A newspaper will attempt to build circulation, build advertising, and build editorial content--all of which increase the requirements for newsprint. The milk carton is a classic example of a trend away from reuse and of source reduction. The plastic-coated paperboard milk carton essentially replaced the refillable glass milk bottle, thus creating a single-use package to replace a reusable one. However, competitive economics has also led to conservation of paperboard, because the basic weight has declined and so has the surface area of paperboard per package.

A grocery sack can be taken back to the store for reuse, can be used to sack newspapers and thus be recycled, or can be used as a waste basket liner in lieu of a new paper or plastic waste basket liner. All of the uses listed, except recycling, would be source-reduction measures activated by individuals.

(1) Industry Practices on Source Reduction

An interesting dichotomy exists in the industry regarding source reduction. Competition drives industries to design products efficiently and to reduce the materials required. Thus, if a package can be configured to use 5 percent less material, this source-reduction measure will be taken. This happened in paperboard milk cartons a few years ago. If an alternate material can be substituted, this will be done too (e.g., paperboard milk cartons have lost their market share to plastic milk containers).

However, when a major source-reduction measure is contemplated, it is resisted or fails because consumers may be reluctant to change their habits or because a substitute would have to be found. Thus, seldom is a product's life or usefulness extended, nor are products eliminated as a source-reduction measure. Paper towels are an example of a product that is very commonly in use in homes and in business and that is not likely to be displaced by cloth.

Another example is that bulk packaging has given way to more individualized packaging in response to consumer buying and living habits; by the same token, this kind of market segmentation has been pursued by marketers of products to increase the salability of their products. In short, significant source-reduction measures seem almost counter to the current trends in the consumer marketplace.

In addition, other significant measures such as electronic banking, electronic newspapers, electronic information systems, and other revolutionary source-reduction measures have not yet reduced the need for paper. Thus, paper consumption has increased while electronic systems have also proliferated. This trend could change in the future with greater consumer acceptance and the electronic capability, but so far it has lead to greater uses for paper.

Finally, many, if not most, paper products are created for use and immediate discard. As information becomes more timely, it becomes obsolete; as advertising carries its message it is succeeded by yet another message. That trend continues.

(2) Economic Considerations

The economic incentive for source reduction of paper products is potential cost savings to product producers.

The principal disincentive is that the entire paper and paper product system's economics are based on high-volume systems producing millions of units or billions of units to minimize unit costs. Some source-reduction alternatives would overturn or would alter this system. Thus, for example, the reusable glass milk bottle no longer fits into the milk packaging system. The system is now based on paperboard and plastic one-time-use containers.

Finally, there is no direct tie-in of product design and use to its ultimate disposal or potential for recycling. Waste management criteria simply are not now recognized as economic criteria for consumers or product producers.

c. Recycling and Reuse

(1) Importance of Recycling

Since paper and paperboard products compose between 30 and 40 percent of the residential and commercial waste stream by weight after removal of some quantity for recycling, their reduction can have a significant impact on the solid waste stream. Recycling waste paper is the most widely used method to reduce the quantities of paper that must be disposed.

The versatility of paper and paperboard products enhances the opportunities for waste paper to be used. For example, waste paper is used in printing/writing paper, newsprint, tissue and toweling, recycled paperboard, gypsum linerboard, and corrugating medium. In addition to these traditional paper markets, waste paper is used as animal bedding and in the manufacture of molded pulp products, cellulose insulation, and hydromulch applications. This wide variety of products further illustrates the versatility of waste paper in recycling applications.

(2) Quantities and Paper Grades Recovered

To present an accurate description of the quantities of waste paper recycled, we must first define some terms. Recycling can include converting scrap as well as postconsumer waste. Because we are most interested in materials in the waste stream, our discussion will focus on the postconsumer quantities.

Table A.A-3 shows that paper products from five major categories are the postconsumer grades most likely to be recycled. These five categories are newsprint, printing/writing papers, paper packaging, corrugated boxes, and boxboard. Overall, the postconsumer recovery of these materials is 22.6 percent of the total postconsumer discards. For the individual grades, recovery ranges from a low of 5.6 percent for paper packaging and boxboard to a high of 41 percent for corrugated. Postconsumer newsprint and printing/writing paper are recovered at rates of 30 percent and 12 percent, respectively. (These values do not include converting scrap or diversion.)

With postconsumer waste paper recovery ranging from 5 to 41 percent, there is room for improvement in the recovery of individual grades (Table A.A-3). However, the grades with the lowest recovery rates--tissue, paper packaging, boxboard, and construction grades--have the least potential for increased recovery. Those with the greatest recovery potential are newsprint (newspapers), container board (corrugated boxes), and printing/writing papers, which can be used as mixed papers or sorted to deink quality. A selected few other products (such as grocery sacks) may also have potential. Therefore, increasing the recovery of these paper products can improve the overall recovery of waste paper from MSW.

(3) Mechanisms for Waste Paper Recovery

In describing the mechanisms for waste paper recovery, there are two primary types to examine: recovery from industrial or commercial establishments and recovery from residences. The following discussion concentrates on these two areas.

(a) Recovery from Industrial and Commercial Establishments

The industrial and commercial sectors were recycling long before organized residential collections were established. Several factors make industrial and commercial recycling practical. First, the quantity of material generated by this sector is concentrated and often large. Second, the scrap generated by businesses is relatively much cleaner or of higher quality than residential scrap. Finally, because of the two preceding facts, the economics are favorable for businesses to recycle. In other words, commercial and industrial businesses have long realized that they can recycle their scrap for the value of the material and save on disposal costs.

Paper converters (such as manufacturers of cartons, envelopes, plates, and the like), produce a very clean product (pulp) substitute. Printers and data processing centers also produce high-quality paper waste of deinking grades (such as computer printout, ledger, and printer's scrap).

Wholesale and retail establishments recover postconsumer scrap, usually in the form of discarded corrugated boxes. Office buildings are the source of sorted or mixed office papers used by deinking mills.

Industrial and commercial businesses typically recycle through source-separation techniques. Thus, employees keep valuable waste paper products separate from the trash. The waste paper is usually stored loose. However, corrugated is more commonly baled or compacted. Recovered paper may then be loaded onto company vehicles and taken to a central warehouse for marketing, or it may be picked up by a waste paper dealer and then marketed. This method is commonly employed for old corrugated container recovery from grocery stores, convenience stores, and so forth.

Another recovery method used to a much lesser extent is "dump and pick" at transfer stations or landfills. In this method, selected industrial or commercial loads of trash (with a high concentration of corrugated boxes) are taken to an area where the corrugated is separated, processed, and sold to end markets. The remainder or residue is disposed of. These selected loads are chosen for sorting on the basis of the amount of corrugated in the load. Usually these loads have a corrugated content of more than 70 percent by weight. Office papers may also be recovered by this approach.

(b) Recovery from Residences

The recovery of waste paper from residences follows one general method--source separation. No matter what the collection method (curbside, drop-off, buyback, etc.), residents separate their recyclables from the trash.

Curbside collection involves residents separating recyclables from their trash and setting the materials on the curb for collection, which most resembles residential trash collection. Old newspapers are the type of waste paper most commonly collected by curbside operations. Once collected, the materials are taken to a processing center where they are prepared to be sold to an end user.

Drop-off centers and buyback centers differ in manner of operation. Drop-off programs are usually operated without staff. In the case of drop-off containers in parking lots, residents take their recyclables to a location and leave them. The material is then hauled to a processing center and prepared for marketing. Drop-off centers do not provide payment to the residents. Buyback centers do pay for some materials such as aluminum cans, newspapers, and glass containers and are usually staffed so that processing, housekeeping, and other functions are carried out during the hours the center is open.

Old newspapers are the primary grade handled through drop-off containers. Drop-off and buyback centers can also be staffed when residents take their materials in. Buyback centers for paper can include waste paper dealers. Both old newspapers and corrugated are usually handled through these centers.

Currently, there is a great deal of activity at the state and local level to establish curbside collection programs for recyclable materials. Newspapers are almost always a required component of these programs. Three states--New Jersey, Rhode Island, and Connecticut--have mandatory source-separation laws. Counties have also mandated source separation of newspapers (e.g., Montgomery County, Maryland, as well as numerous cities across the United States). The activity is so great at the state and local level that any cataloging of source-separation programs would be quickly obsolete.

In New York City, several effective programs have been developed to serve high-rise apartments, which generally lack storage space for recyclables.

(4) Technical Considerations

Although there are many aspects of the paper recycling industry that could be discussed here, the emphasis in this section is on the technical aspects of the use of waste paper at the recycling mill.

(5) Present Practices

Over the past century, the use of waste paper in manufacturing products has been refined and improved. Mills must continuously adapt to changes that are required in final products. For example, the increased use of laser printers has forced many mills that use recovered computer printout to modify their deinking operation. While some operations have changed to accept laser print, other mills have not been able to adapt; therefore, a separate classification has been made in the waste paper industry to distinguish the types of computer printout.

From the preceding example, it should be noted that contaminants of one form or another will cause the greatest technical problems in recycling. In addition to laser print, other contaminants vary depending on what products a mill is manufacturing. For example, contaminants to a printing/writing paper manufacturer are very different from those to a construction board manufacturer. In general, recycled paperboard products can tolerate a wider variation of contaminants than bleached paper products (such as printing papers and form bond). The type of waste paper or fiber is one of the major limitations.

Another technical barrier may be the quality and strength requirements of a product. There is very little recycled printing/writing paper produced compared to total production. However, it is difficult to separate technical barriers from economic barriers. The recycled product may be more costly to produce rather than present insurmountable performance or quality problems. Also, end users of recycled printing/writing papers may need to be educated that slight differences in brightness or of appearance are normal for recycled paper products.

Table A.A-5 illustrates the suitability of the principal paper grades by various types of mills. Mills that do not have wood pulp capacity use waste paper wholly or partly as their raw materials. Some may use market pulp exclusively. Mills that have wood pulp capacity can also be equipped to use waste paper as a supplemental furnish. If the particular grade and type of mill is technically suitable for use of waste paper, the entry is "yes." Special situations are footnoted.

Table A.A-5 also illustrates which types of products and manufacturing operations should be considered to increase recycling. For example, in the case of newsprint, recycling can occur by building a new mill that uses 100 percent recycled fibers; or current virgin-fiber mills that are now using wood pulp might be able to add capacity to use recycled fiber. In the case of semichemical corrugating medium, few if any mills can be economically equipped for substitution of additional recycled fibers. However, increased recycling can be attained by building a new mill for 100 percent recycled material or by increasing the capacity of such mills.

In many of the grade categories of the selfstanding mills without virgin-pulp capacity, the product produced is identified and marketed as "recycled" (e.g., deinked newsprint, recycled medium, recycled linerboard, etc).

Finally, in the case of current practice, several technical barriers prevent the use of waste paper in terms of final product

TABLE A.A-6

SUITABILITY OF PRINCIPAL PAPER GRADES FOR RECYCLING BY VARIOUS MILL TYPES

Paper or Paperboard Product	Suitable for Use of Recycled Paper: Self-standing Mill Without Wood Pulp Capacity[1]	Suitable for Use of Recycled Paper: Integrated Wood Pulp and Paper Mill Capacity[2]
Paper		
Newsprint	Yes	Yes
Printing/writing papers	Yes[6]	[3]
Paper packaging	No	Yes
Tissue/toweling	Yes	Yes
Paperboard		
Corrugating medium	Yes	[4]
Linerboard	Yes	Yes
Other paperboard	Yes	[3]
Specialty		
Construction paperboard	Yes	[5]
Molded pulp	Yes	Yes
Cellulose insulation	Yes	[5]

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[1] Products can or do contain a high percentage of recycled fibers; some are 100 percent recycled fiber.

[2] Mills are able to use incremental amounts of recycled fibers.

[3] Mills are not usually equipped to accept supplemental furnish of postconsumer waste paper.

[4] This type of mill requires box plant cuttings, but it is not equipped to clean postconsumer grades.

[5] These products are almost always made of recycled paper.

[6] The recycled grades rely on market pulp, pulp substitutes, and some deinking to achieve product performance characteristics.

Source: Franklin Associates, Ltd.

specifications and performance, most notably in printing/ writing papers and in wet or oily food-contact paperboard. In the case of liquid, oily, or moist food contact with packaging, the Food and Drug Administration provides guidance in 21 CFR 176.260 "Pulp from Reclaimed Fiber." In the case of dry food products, the use of recycled paper products has been common for decades.

In the case of printing/writing papers, the technical issue relates more to availability of high-quality waste paper as pulp substitutes that can be cleaned by deinking processes to meet product performance criteria.

There may also be economic and/or market barriers: for example, recycled printing/writing papers competing with commodity grades such as copier paper, forms bond, and the like.

Changes in recycling mills have been observed just over the past 5 years. Improvements are being made that allow newer mills to accept grades of waste paper that their older competitor mills do not use to produce the same quality product. Mills that use recycled tissue and toweling seem to be making the greatest strides in this area.

Along these same lines, changes will be needed in the deinking process in order to handle the new printing types that are being considered now and in the future. Research and development will be required to keep recycling growing.

The environmental considerations may be significant too, especially where deinking processes are used. The sludges may contain contaminants (such as inks, coatings, and other residues) that are removed in the deinking process.

d. Economics and Markets

(1) Supply and Demand Issues

Waste paper recycling has been supply and demand driven since its beginning. The demand for final products manufactured by recycled-paper mills initially establishes the demand for waste paper. Therefore, when mill production is down because product sales are down, so is demand for waste paper.

The economics of waste paper are very similar to any commodity. For example, when demand for waste paper is high, so are the corresponding prices. Conversely, when demand for waste paper is low, the prices are correspondingly low. The actual demand for waste paper is established by the recycled mills that purchase the scrap. Therefore, demand has historically set the price, which in turn has affected the supply of waste paper. In turn, waste paper dealers practice similar pricing for paper recovery. Thus, when mill-buying prices are low, waste paper dealers lower the prices that they pay to suppliers in order to decrease the supply of material. Through this system, supply and demand of waste paper have been kept in balance.

We are now entering a new era, however, with significant activity from community-based recovery programs. Here programs will remove material from the waste stream to reduce the solid waste stream. The communities are not primarily concerned with keeping the supply and demand in balance. Therefore, as more community-based recovery programs come on line and larger amounts of waste paper are recovered, there are likely to be changes in the current waste paper system. These changes will not cause the system to collapse, but there will be a definite transition period for the industry. In fact, some changes are already being observed. Waste paper inventories are usually not used to balance supply and demand. Rather, excessive inventories are sent to a landfill or sold at distress prices. The key, of course, is for markets to expand as fast as supply does.

The issue of supply-demand-price balance will be demonstrated in the marketplace when supply overtakes demand and does not fall back. So far, increased recovery has been absorbed by mills and exports. However, as more municipal collection programs become activated, the supply of waste paper (especially newspapers) will exceed demand.

(2) Capital Requirements

When comparing the virgin-paper industry and the recycled-paper industry, many similarities and many differences are seen. One difference is in the area of capital funding required.

Whether we are discussing the recovery of waste paper or the manufacture of a recycled paper product, both operations are less capital intensive than their virgin-material counterparts. The recovery of waste paper versus the harvesting of trees is labor intensive for the waste paper, while the harvesting is quite capital intensive. On the manufacturing side, the capital required for a greenfield-virgin mill is much higher than a greenfield-recycled mill. Therefore, capital requirements overall are on the side of the recycling industry, although other factors have characteristically counterbalanced their effect. Integrated pulp and paper mills are more energy self-sufficient with respect to purchased (fossil) fuels than are recycled-paper mills. Most importantly, the per ton costs are often lower for wood-pulp-based mills, and the ample supply of forest resources makes wood pulp a more secure and controllable source of raw materials. The market product or endproduct may also dictate the source of fiber.

(3) Market Requirements

Recycled-paper mills are usually located close to waste paper supplies and to their customers. By locating so as to best serve their customers, recycling mills will have different waste paper needs and supply situations. Waste paper recovery occurs in areas where concentrated amounts are generated (e.g., large commercial establishments, metropolitan areas, etc.).

(4) Regional Variations

The present distribution of paper recycling capacity is given in Table A.A-6. (Detail is available by grade of recyclable paper--mixed, newspaper, corrugated, pulp substitute,

TABLE A-7

GEOGRAPHIC DISTRIBUTION OF MILL CAPACITY
FOR WOOD PULP AND WASTE PAPER AS FIBROUS RAW MATERIALS, 1988
(In thousand short tons annual capacity)

Region	Fiber Capacity	Fiber Percent of Total	Total Wood Pulp	Total Waste Paper	Waste Paper (percent)
New England	5,666	7.1	4,215	1,342	6.7
Middle Atlantic	5,619	7.0	3,026	2,559	12.8
East North Central	12,215	15.3	6,482	5,678	28.3
West North Central	1,703	2.1	1,111	571	2.8
South Atlantic	20,052	25.1	16,485	3,510	17.5
East South Central	10,623	13.3	9,272	1,329	6.6
West South Central	11,970	15.0	10,371	1,802	9.0
Mountain & Pacific	11,951	15.0	8,690	3,258	16.2
Total USA	79,836	99.9	59,451	20,050	99.9

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[1] Standard Bureau of Census regions.

Note: "Other fibers" are omitted from this table.

Source: Reference 3.

high-grade deinking--from the source document).[7] In addition, it should be noted that the principal ports of export are in the Middle Atlantic States (New York); the Mountain and Pacific States (Los Angeles, San Francisco, and Seattle); and the West South Central States (Laredo, Texas).

Several points are significant. First, the distribution of capacity is very uneven geographically and does not necessarily match up with major population centers where MSW management practices are moving toward higher levels of recovery of postconsumer grades of waste paper--principally newspapers, corrugated boxes, and office papers. These grades are usually shipped short distances, while pulp substitutes and deinking grades may be shipped a long distance. Second, the need for any given grade may be quite different from region to region while the source of recovery is many hundred miles away. Third, if the waste paper capacity is to match up with generation and recovery activity, then additional capacity will be needed in the Middle Atlantic States, in the New England States, and, to a lesser extent, elsewhere. Yet these regions are where capacity to use waste paper is increasing more slowly than in some other areas.

The solution may be to stimulate capacity closer to generation and recovery points and to stimulate demand for recycled-paper products in proximity to their manufacture point.

(5) Incentives and Disincentives

Some State governments have provided tax credits or exemptions for recycling equipment purchases, grants, low-interest loans, industrial bonds, and accelerated depreciation. These incentives were aimed at encouraging recycling businesses to improve their systems and increase their capacity in hope of increasing the demand for waste paper. Several incentive programs remain active; however, there is discussion of which programs are most effective. For instance, a detailed study of tax incentives for Illinois indicated that tax incentives at the State level were not an effective method for encouraging recycling, because the tax liabilities at the State level are low (zero to 1 percent of sales) and would not present a significant incentive. Therefore, each location must compare the incentives with local conditions and industry needs. However, this issue has not been addressed at the Federal level recently and could have a result different from the State or local level.

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[7] American Paper Institute, 1987.

(6) Role of Government Procurement

An important aspect of recycling is that recovering material from the waste stream is not recycling. Waste paper must be recovered and made into a new product to complete the recycling loop. Governments at the Federal, State, and sometimes the local level have developed recycled-paper procurement practices as a means to stimulate the demand for recycled-paper products.

Typically there is a department or branch within Federal, State, and local government specifically in charge of purchasing. To date the most active purchasing of recycled products has occurred on the State level.

Government purchases of paper are mostly the printing/writing and tissue grades. The paper products most likely to be affected by Government purchasing would be printing/writing paper. It is very probable that most tissue and toweling bought by Government already contains recycled fibers. Therefore, printing/writing paper purchases have the greatest room for increasing recycled-paper purchases. Finally, the role of government is twofold: first, to set a minimum-content standard for recycled materials contained and, second, to provide leadership in stimulating additional recycling.

The EPA published its final revised procurement guideline for paper and paper products on the 22nd of June 1988 in the Federal Register. The guideline provides for the use of postconsumer recovered materials in most grades of paper and, in the case of printing/writing papers, for the use of waste paper. The guideline implements Section 6002(e) of the Resource Conservation and Recovery Act of 1976 (RCRA), as amended, which requires the EPA (1) to designate items that can be produced with recovered materials and (2) to prepare guidelines to assist procuring agencies in complying with the requirements of Section 6002. Once the EPA has designated an item, Section 6002 requires that any procuring agency using appropriated Federal funds to procure that item must purchase such items containing the highest percentage of recovered materials practicable. The guideline establishes minimum content standards (MCS) for paper products. For example, most printing and writing papers have an MCS of 50 percent waste paper; for tissue products the MCS is 20 to 40 percent of postconsumer waste paper depending on the nature of the product.

Many states have evaluated their specifications to ensure that recycled paper is not excluded from bidding and have provided either a set-aside or price preference for recycled products. A set-aside program ensures that some portion of the purchases will be made of recycled paper (e.g., 25 percent of all copy paper). This figure does not refer to composition of the paper. The price preference allows recycled products to compete with the virgin-fiber paper with a 5 to 10 percent price preference usually given to the recycled product. In this way, if a recycled product's bid price is 3 percent higher than a virgin product's bid price, than the recycled product would win the contract.

The states that have active paper procurement programs are California, Maryland, New York, Oregon, Rhode Island, and Washington. Other states such as Connecticut, Florida, Illinois, Iowa, Maine, Michigan, Minnesota, Missouri, New Jersey, Ohio, Texas, and Vermont have some legislative activity in paper procurement.

(7) Role of Private Procurement

As in the case of Government procurement, private procurement of recycled products has an even larger role in improving recycling conditions and completing the recycling loop. If more customers request recycled products, then more waste paper will be needed to meet this demand. Private companies purchase many more tons of material than governments purchase. Therefore, a change in their buying habits can have a significant impact on the recycling industry.

While the private sector has a greater ability to have an impact on recycling, the private sector also tends to use its traditional specifications and to buy competitively. Packaging and containers used by industry convey a company image. Even though recycled-paper products could perform the same function, some companies may choose not to use recycled materials. For example, paperboard containers for perfumes, toothpaste, cigarettes, and many other products are usually made from virgin paperboard. Cost competition may also work against the recycled-paper product, and the functionality of the package may require an appearance that the marketer can achieve best by the use of virgin-fiber material.

Newspaper publishers now use well over 1 million tons per year of deinked newsprint. In fact, about 25 percent of the newsprint capacity in the United States is deinked newsprint. Nonetheless, newspaper publishers probably hold the key to greater use of recycled newsprint. However, many large publishers have (virgin) mill ownership or longstanding supply contracts with Canadian mills, which provide over 60 percent of the newsprint consumed in the United States, and with domestic mills.

Finally, as the solid waste "crisis" has been popularized in public awareness, some companies are making moves to consciously purchase more products containing recycled paper (such as printing/writing papers).

e. Nonmarket Factors

Recycling and reusing paper products are perhaps more influenced by nonmarket factors, at least as they relate to recovery of recyclable paper. Citizens of every age have a long history of participating in newspaper drives and collecting newspapers for personal or charitable gain. Public interest has been stimulated again, and no other material group has the length of history of recovery (not even aluminum cans).

Public education combined with community-based recovery programs are a key. Old newspapers are almost always the focus of residential collection no matter how few or how many materials may be collected. Today citizens in all parts of the nation are aware of the solid waste "crisis" and the capacity limitations of landfills.

Another nonmarket factor is the public's concern for environmental considerations to reduce dependence on landfills, to usefully recover materials, and to reduce pollutants.

The awareness of natural resource conservation is another nonmarket factor. Conservation of forest resources has been a principal emphasis of natural resource conservation. There may now be some awareness developing that land for landfills is a resource to be conserved and that energy recovery of otherwise unusable waste paper is also an energy conservation measure to which paper can make a significant contribution.

f. Paper Recycling Practices in Other Nations

Industrialized nations that are limited in forest resources have developed highly efficient waste paper collection and utilization systems. In addition to high levels of collection, many countries import waste paper from the United States. It is interesting to note, however, that the maximum recovery of waste paper in industrialized nations does not exceed 50 percent. The data shown in Table A.A-7 give that information.

In EEC (European Economic Community) countries, the waste paper utilized[*] in paper product manufacture ranges from 40 to 60 percent; recovery of waste paper ranges from 26 to 46 percent. This recovery total averages above the United States in percentage, but the United States falls in the lower end of the range.

By contrast, the Nordic nations use much less waste paper than the United States and recover only slightly more on a percentage basis. Likewise, Canada is well behind the United States in these two categories. Thus, of the forest-rich nations, the United States does quite well and is well ahead of these nations in terms of utilization and only slightly behind them in recovery percentage.

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[*] Utilization is defined as "waste paper consumption as a percentage of total paper production."

TABLE A.A-8

WASTE PAPER RECOVERY, CONSUMPTION, AND TRADE
(1,000 metric tons)

Country	Recovery	Consumption	Imports	Exports	Percent Utilization[1]	Percent Recovery[2]
France	2,341	2,289	423	476	41	34
Germany, West	4,548	4,073	479	949	43	40
Italy	1,380	2,046	667	0	44	26
Netherlands	1,177	1,228	461	372	60	46
Spain	1,147	1,860	413	15	59	43
United Kingdom	2,355	2,147	40	248	54	29
EEC Totals[3]	14,399	14,408	2,613	2,534	47	35
Finland	363	280	27	83	4	25
Norway	141	124	26	43	8	24
Sweden	799	748	130	135	11	40
Nordic Totals	1,303	1,152	183	261	7	32
Austria	414	866	516	44	40	43
Switzerland	498	465	112	145	43	40
Other Western Europe Totals	912	1,331	628	189	41	41
Canada	1,077	1,595	634	233	10	20
United States	19,586	15,862	91	3,401	25	28
North America Totals	20,663	17,457	725	3,634	26	27
Japan	10,511	10,730	352	127	51	50
Republic of Korea	990	1,846	856	0	67	38
Taiwan	1,219 e	2,485 e	1,266	0	98	48 e
Asia Totals[4]	16,378	18,461	3,010	536	45	36
Australia	697	663	1	46	29	14
Venezuela	271	322	62	0	54	35
Latin America Totals[5]	3,218	3,876	886	8	39	31
Africa	551	621	78	0	26	17
WORLD TOTALS	62,026	61,677	8,262	7,586	30	31

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[1] Percent utilization is defined as wastepaper consumption as a percentage of total paper and board production.

[2] Percent recovery is waste paper collection as a proportion of total paper and board consumption.

[3] Includes Belgium, Denmark, Greece, and Portugal.

[4] Includes China, Hong Kong, India, Indonesia, Malaysia, Philippines, Thailand, and Turkey.

[5] Includes Argentina, Brazil, Chile, Columbia, and Peru.

e = PPI estimate.

Source: Pulp and Paper International. Annual Review, 1986.

Japan has attained the highest recovery and utilization rate of 50 percent. The only other two nations approaching that level are Hong Kong and Taiwan.

Only a few countries besides the United States export a great deal more waste paper than they import, and none has the high ratio of exports to imports that the United States has. The countries with the most significant net exports are West Germany and the United Kingdom. The principal reason that exports are so high from the United States is that paper recovered in quantity represents "fresh" fiber to forest-poor nations because of the high quality of these products.

The conclusion that can be drawn is that the United States, with its vast forest resources, is a more balanced nation than has been portrayed in some quarters on the use and recovery of waste paper in comparison to other industrialized nations. However, the potential is also very great to do more in the United States.

g. Incineration and Energy Recovery

(1) Role and Contribution of Paper Wastes to Energy Recovery

Paper discards compose over one-third of MSW. Paper is a preferred component in MSW used for energy recovery because of its high heat energy value, low moisture content, and low ash content. Both the high heat energy from paper and the low moisture content maximize the recoverable heat energy when paper is used as fuel. The low ash content remaining after burning paper reduces both ash handling and disposal. The principal concern is whether some products containing heavy metals (such as inks and pigments used in printing) are present in significant quantities.

(2) Quantitative Impacts of Paper on Energy Recovery

A comparison of the paper components with other MSW components is contained in Table A.A-8. Paper discards accounted for 35.6 percent of total MSW net discards estimated for 1986, but accounted for nearly half of the total heat energy estimate.

Energy values shown for paper wastes range from over 7,000 Btu per pound of higher heating value (HHV) for newspaper, to about 7,200 Btu per pound for the "other paper" category. Corrugated, other paperboard, and paper packaging are essentially the same and are estimated at 7,300 Btu per pound. These energy values compare with an estimated nearly 5,400 Btu per pound for all MSW. This latter value is higher than HHV's often quoted for MSW, but the reason may be a noticeably higher percentage of combustible materials in MSW than was present a few years earlier (especially plastics).

The moisture content of the paper waste components is estimated at 8 percent. This figure compares with over 20 percent for all MSW. The comparatively low moisture content of paper is a further advantage in energy recovery since less heat energy is used to vaporize moisture; the heat energy used for moisture vaporization is not recoverable.

Ash content of the paper waste components is estimated in Table A.A-8. Newspapers are shown as having the lowest ash content--less than 2 percent--whereas the "other paper" category is shown at approximately 5 percent ash. Corrugated, other paperboard, and paper packaging have only a little more ash content than newspaper.

It is clear from Table A.A-8 that removing paper from MSW has a greater than average impact on energy recovery potential. However, newspapers and corrugated boxes make up the major waste

TABLE A.A-9

MSW NET DISCARDS* COMPOSITION/ENERGY VALUES
(1986)

MSW Component	Annual Quantity^{1} (million tons)	Percent of Total MSW	Moisture Content as Generated^{2} (percent)	Ash Content as Generated^{3} (percent)	Higher Heating Value^{3} (HHV) (Btu/lb)	Percent of Total MSW HHV
Newspapers	8.8	6.3	8.0	1.84^{4}	7,844^{4}	9.2
Corrugated Boxes	11.4	8.1	8.0	2.16^{4}	7,309^{4}	11.0
Other Paperboard	5.1	3.6	8.0	2.16^{4}	7,309^{4}	4.9
Paper Packaging	3.9	2.8	8.0	2.16^{4}	7,309^{4}	3.8
Other Paper	20.9	14.8	8.0	5.04^{4}	7,198^{4}	19.8
Glass	11.8	8.4	2.0	--	0	0
Ferrous Metals	10.6	7.5	2.0	--	0	0
Aluminum	1.7	1.2	2.0	--	0	0
Other Nonferrous Metals	0.3	0.2	2.0	--	0	0
Plastics	10.3	7.3	2.0	3.46^{4}	15,982^{5}	21.6
Rubber and Leather	3.9	2.8	2.0	N/A	10,769^{5}	5.6
Textiles	2.8	2.0	10.0	1.36^{4}	8,685^{4}	3.2
Wood	5.8	4.1	15.0	2.16^{4}	7,328^{4}	5.6
Food Wastes	12.5	8.9	70.0	1.97^{4}	2,840^{4}	4.7
Yard Wastes	28.3	20.1	50.0	22.1^{4}	2,876^{4}	10.7
Miscellaneous Inorganics	2.7	1.9	2.0	--	0	0
Total MSW	140.8	100.0	20.5		5,392	100.1

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*Discards (as generated) after materials recovery and before energy recovery.

NA = Not Available.

[1] Franklin Associates, Ltd. Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988), prepared for the U.S. Environmental Protection Agency, Office of Solid Waste, March 31, 1988.

[2] Ralph M. Parsons Co. Engineering and Economic Analysis of Waste-to-Energy Systems, prepared for the U.S. Environmental Protection Agency, June 1977.

[3] Figures are based on adjusting values from the references indicated to account for the moisture contents of "as generated" discards.

[4] Robinson, W. D., PE, Ed. The Solid Waste Handbook, A Practical Guide, John Riley & Sons, 1986.

[5] Franklin Associates, Ltd. Waste Paper, The Future of a Resource, 1980-2000, Report for the Solid Waste Council of the Paper Industry, December 1982.

paper recyclables, and they represent approximately 6 percent and 8 percent, respectively, of MSW net discards. Thus, even if sizable increases in recycling of these two paper components should occur, the impact on MSW energy recovery potential would not be severe. For example, removal of about half of the net discards of newspaper and corrugated boxes would effect only about a 3 percent decrease in the HHV (Btu per pound) of the remaining MSW discards. The seasonal variation alone may have more than a 100 percent variation in Btu value, and daily fluctuations will exceed 3 percent.

In the recent past there has been a competitive and even hostile stance among the waste-to-energy vendors, financing agencies, and recycling advocates. Often municipal officials were forced to or did support the waste-to-energy solution, partly because it was a one-step solution to solid waste management. Also, the waste paper industry strongly fought restrictive flow control ordinances that could force waste paper suitable for recycling into waste-to-energy plants.

Most waste-to-energy vendors now support recycling to the point of publicly endorsing and even practicing recycling at their plants. Community officials place priority emphasis on recycling. Some, like the New York State Department of Environmental Conservation, have required that a recycling program be part of any waste-to-energy facility. Waste-to-energy plants are now even sized to handle MSW with an allowance for a community recycling goal.

The change has been so dramatic in the last 2 or 3 years that there seem to be only isolated areas where the competition and controversy still are a factor. But, the trend and practice decidedly favor "recycle first," and then burn or landfill what cannot be recycled.

There are, of course, barriers and incentives to energy recovery. In the case of paper, the incentives are fairly obvious:

- High Btu value and thus fuel value
- Low ash
- Very high volume reduction
- Useful recovery of unrecyclable paper
- Relatively high value in dollars per ton as fuel

The barriers are more generic to waste-to-energy than to the paper components. The only two barriers that are, perhaps, related to paper are

- Potential competition between fuel value and recycle value
- Potential for undesired emissions or contaminated ash from materials applied to paper products (e.g., heavy metals found in some inks and pigments)

At present, the EPA and a host of other agencies are placing a very high emphasis on how to address the issue of incinerator ash and heavy metals therein.

h. Landfilling

(1) How Paper Performs in Landfills

Paper is the major component in most municipal landfills; approximately 36 percent of MSW landfilled in the United States in 1986 (by weight) was estimated to be waste paper. However, paper is among the slowest of the organic materials in landfills to decompose. Difficulty is encountered in biologically decomposing paper, which is composed largely of cellulose but also contains lignin, which tends to shield the cellulose from microbial attack.

Low moisture content in the landfill is probably the major reason why this degradation does not occur. Most landfill construction today is designed to prevent rainfall from contacting and being absorbed into the underlying layers of waste. Without added moisture from rainfall or another source, much of the paper will remain in its original condition indefinitely.

Finally, paper products such as milk cartons and some other types of food packaging that are plastic-coated may act like plastics in a landfill (i.e., they may essentially be resistant to degradation). There is, however, no definitive data available to confirm this observation.

(2) Impact of Paper on Landfill Volume

As previously mentioned, waste paper was estimated to represent about 36 percent of the total tonnage of MSW landfilled in the United States in 1986. Paper is, therefore, the single largest MSW component by a considerable margin.

Paper has an even greater impact on landfill volume. Studies performed on excavated wastes from three modern landfills in Tucson, Arizona; south of Oakland, California; and near Chicago, Illinois, showed the following weight to volume relationship for paper.[9] (See Table A.A-9.)

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[9] University of Arizona. "The Mullens Dig, A Working Outline," The Garbage Project, Bureau of Applied Research in Anthropology, University of Arizona, Tuscon, Arizona, 1987.

TABLE A.A-10

SORT RESULTS: ALL LANDFILLS

Paper Category	Mean Percent of All Components by Weight	Mean Percent of All Components by Volume	Ratio of Volume to Weight
Newsprint	11.41	14.11	1.24
Cardboard	3.47	4.55	1.31
Packaging Paper	10.04	16.22	1.62
Nonpackaging Paper	7.59	11.00	1.45
Glossy Magazines	1.96	1.63	0.83
Totals	34.47	47.51	1.38

Source: The Garbage Project, Bureau of Applied Research in Anthropolog
University of Arizona, Tucson, Arizona.

These results clearly demonstrate that waste paper uses a high volume of landfill space. The total ratio of volume to weight for all waste paper examined indicates volume exceeding weight by 38 percent (34.5 percent by weight and 47.5 percent by volume). Thus, at current quantity estimates, waste paper may be expected to require almost half of the landfill volume needed for MSW disposal. Some other comparisons of weight and volume from the same source are plastics--4.8 percent by weight and 16.3 percent by volume and glass--2.4 percent by weight and .9 percent by volume.

i. Other Considerations

A few points are relevant with respect to recovery and recycling of waste paper from MSW. State and local governments have the objective of reducing the amount of materials going to landfills and incinerators. Thus, they will likely encourage maximum collection and processing of waste paper not already being recovered by private efforts. As a result, the quality of recovered paper may suffer, and there will be times of oversupply. During these times, the ongoing efforts of private collectors may be displaced, and the local municipal programs could be flooded with waste paper. One alternative may be to burn paper for energy recovery in periods of significant oversupply, especially that for which minimal demand exists.

The paper industry and its waste paper dealer system is in the difficult position of increasing demand for recycled products and providing capacity as collection increases. Providing a use for all recovered paper will require a great deal of effort on the part of industry, citizens, and government.

3. ISSUE IDENTIFICATION

a. Capacity as It Relates to Solid Waste Management Options

Paper discarded for disposal has a significant weight and volume impact on any solid waste management system. The following issues are the principal ones with respect to solid waste management options.

(1) Landfills

Paper occupies almost 50 percent of the volume and about 36 percent of the weight in a landfill. Therefore, it has a substantial impact on landfill capacity and lifetime. In addition, paper products are only slowly degradable under the design criteria of landfills in spite of their basic source as tree fibers.

(2) Incineration

Paper makes an excellent fuel as a waste material since it has a high Btu content per pound and reduces to an ash content of 2 to 3 percent. Paper accounts for over 50 percent of the heat content in an average ton of MSW. Any unacceptable emissions or ash concentration of heavy metals would be derived from inks, pigments, or other substances applied to paper in the converting process.

(3) Recycling

Several components of paper products are quite recyclable, specifically newspapers, corrugated boxes, and office papers. Somewhat over 50 percent of paper products reaching landfills or incinerators now could theoretically be removed for recycling. This is unlikely to occur, of course. Even with higher rates of removal from MSW, the fuel value of MSW is not significantly altered. There are substantial issues about recovery and collection of paper for recycling and of the paper industry's capacity to absorb and to market a greatly increased quantity of waste paper and recycled paper products. As the recovery rate approaches 50 percent, the technical issue of fiber deterioration arises. Also, a fuel grade of paper may be a consideration after the limits of recycle are approached.

(4) Toxicity

Since paper in its pure form consists of wood fiber, it has no inherent toxic characteristics. There is some potential for undesired substances to appear in the manufacturing process. For example, some minute quantities of dioxin have shown up in tests of products where the mill uses chlorine bleaching. At this point, a more extensive test program is under way supported by the paper industry. However, it is in the converting process (e.g., printing) that potentially "bad actors" might appear. To the extent that ink and pigments with heavy metals are used on printed material (e.g., magazines), then the association of very small quantities of lead and/or cadmium is established. The process that seems most likely to produce unwanted residues is incineration, although landfill leachate could potentially have some of these substances derived from paper. At this point, there is virtually no definitive information available relating to paper and its role in incinerators or landfills with respect to potential "bad actors."

Finally, the sludges produced as a result of paper recycling may contain some of these same toxic materials in the same chemical form as that used on or with the product originally.

b. Fiber as a Material Resource Base

The United States is fortunate to have vast forest resources. A significant percentage of wood pulp is derived from tree farms and from the byproducts of lumber operations. Trees are also a renewable resource, since trees can be grown as a crop.

There appears to be merit in conserving this renewable resource, perhaps more as a measure to alter the pattern of disposal and thus to conserve landfill space.

After its use, paper may be burned for its energy content or recycled. Many pulp mills are energy self-sufficient, while recycling mills are not. Even so, the fibrous materials content can be used again and, eventually, the energy value can be extracted.

c. Summary of Issues of Significance and Areas of Opportunity to Resolve

The principal issues of significance with respect to paper are

- The weight and volume impact of paper on MSW
- The associated inks or other materials that might contain undesired substances

The principal opportunities to resolve these issues are

- To increase the rate of recycling significantly, which necessitates an increase in demand by end users
- To recover the energy content of otherwise unusable paper
- To remove from use potentially harmful substances that are applied to paper
- To reduce the amount of paper products requiring waste management

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4. Franklin Associates, Ltd. Feasibility of Tax Incentives for Purchases of Recycling Equipment or Recycled Products prepared for Illinois Department of Energy and Natural Resources, Energy and Environmental Affairs Division, May 1987.

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TABLE OF CONTENTS

APPENDIX A

B. GLASS

Page

1. QUANTITIES AND TYPES OF GLASS WASTE A.B-1

2. CURRENT WASTE MANAGEMENT PRACTICES A.B-21
    a. Landfilling A.B-21
    b. Recycling A.B-24
    c. Recycling of Residentially Generated Glass A.B-27
    d. Recycling of Commercially Generated Glass A.B-34
    e. Recycling of Industrially Derived Glass A.B-36
    f. Selected State Recycling Programs A.B-37
    g. International Glass Recycling A.B-42
    h. Source Reduction A.B-49

REFERENCES A.B-50

APPENDIX A
MAJOR WASTE STREAM COMPONENTS

B. GLASS

1. QUANTITIES AND TYPES OF GLASS WASTE

In a recent study prepared for the U.S. Environmental Protection Agency (EPA), Office of Solid Waste, by Franklin Associates, Ltd., a summary of estimates of historical municipal solid waste (MSW) quantities and composition from 1960 to 1986 was presented and projections were made to the year 2000. According to the study, approximately 11.8 million tons of waste glass (8.4 percent of the total MSW) were discarded into the MSW stream in 1986; these figures represent discards after materials recovery and before energy recovery.[1] The amount of glass recovered from MSW in 1986 was reported as 1.1 million tons, or 8.5 percent of the gross total of discarded glass.[2] The study further noted that in 1986 the average per capita production of MSW was calculated at 3.19 pounds per day, .27 pounds of which were glass waste.[3]

The fraction of the waste stream composed of glass increased steadily until the early 1980's, then began a slow decline. Figure A.B-1 graphically represents the amount of glass discarded into the waste stream from 1960 to 1986, with projections made through the year 2000. In 1960, glass represented 8 percent of the waste stream; in the early 1980's the percentage of glass in

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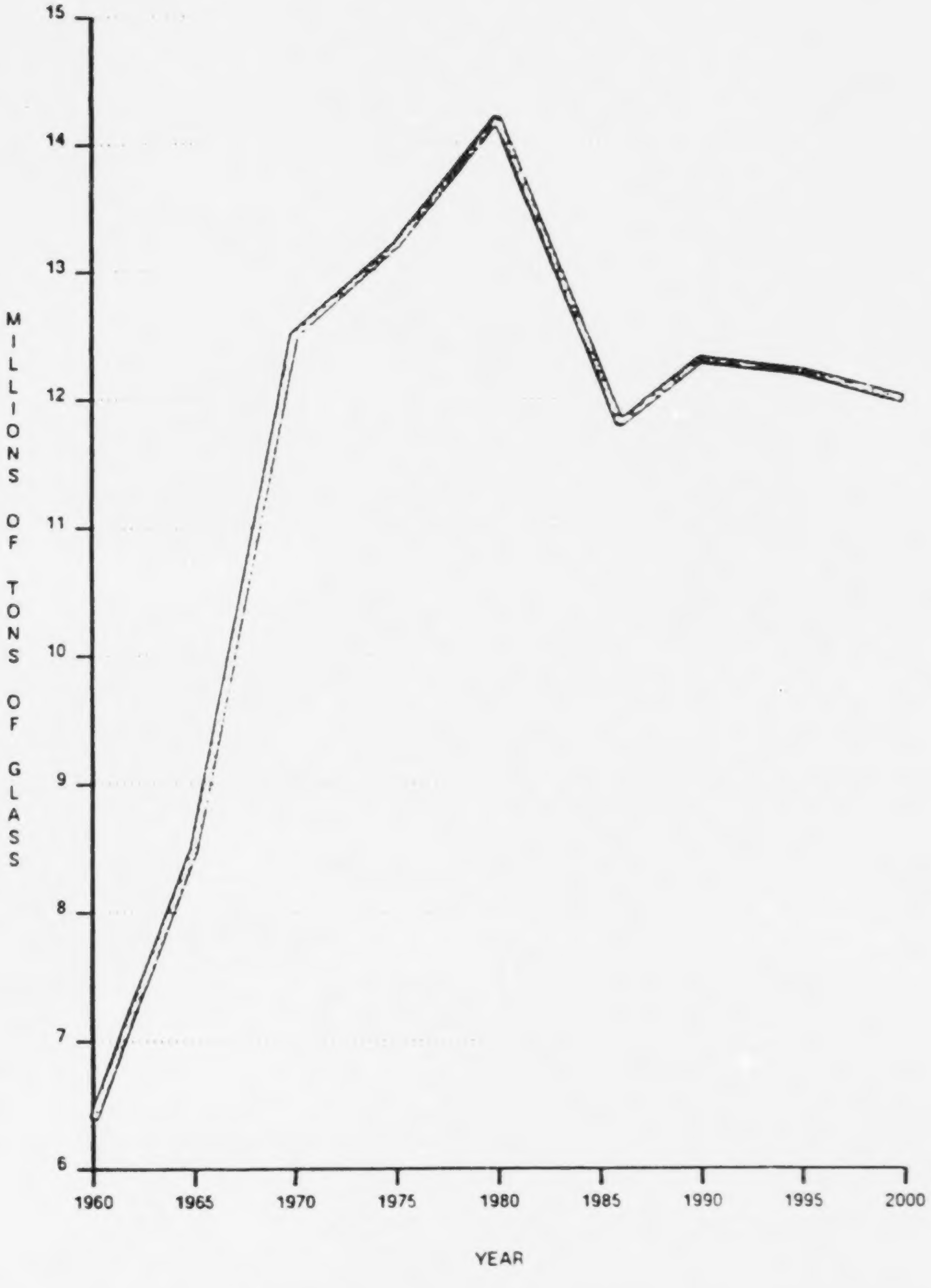
[1] Franklin Associates, Ltd. Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988), Final Report, prepared for U.S. Environmental Protection Agency, Office of Solid Waste, March 30, 1988, p. S-2.

[2] Franklin, p. 21.

[3] Franklin, p. 24.

FIGURE A.B-1

ACTUAL GLASS DISCARDED INTO MUNICIPAL WASTE STREAM



Actual glass discarded into municipal waste stream, after materials recovery and before energy recovery. Volume of glass is projected for years 1990 through 2000.

Source: Franklin Associates, Ltd., March 1988.

MSW rose to over 11 percent. Since that peak, the percentage of glass in the waste stream has been decreasing, with 8.4 percent glass being discarded in 1986 and 7.1 percent being projected for the year 2000.[4] This decrease in glass waste is attributed primarily to the displacement of glass containers by lighter-weight aluminum and plastic in the marketplace.

Glass manufacturers produce three primary categories of products: containers, flat glass, and pressed and blown glass. Flat glass is used mainly for windows; pressed and blown glass has ornamental and decorative applications in addition to being used for such products as light bulbs. However, containers make up approximately 70 percent of all glass manufactured and account for 90 percent of all glass in MSW.[5]

According to the Franklin Associates' report, total glass containers discarded increased from 5.9 million tons in 1960 to 13.3 million tons in 1981. In 1986, the tonnage of container glass in MSW decreased to 10.7 million tons. In percentages, glass containers were over 7 percent of the total discards in 1960, rose to approximately 11 percent in the peak year (1981), and dropped to 7.6 percent for 1986. The study further concludes that the weight of glass containers in the waste stream is projected to remain relatively constant--at less than 11 million tons, or 6.4 percent of the total MSW, in 2000.[6]

Reports from the Department of Commerce indicate that the number of glass containers shipped from manufacturers in 1987 rose by 3.5 percent above 1986 shipment figures--reflecting the glass industry's second consecutive year of increases. Table A.B-1 indicates the number of glass containers shipped (in thousands of gross), by product type, from 1980 to 1986. The Commerce Department lists the following glass qualities that are expected to sustain its market share growth: high consumer acceptance, image of purity and prestige, use in microwave ovens, barrier properties, and ability to be recycled. According to The Nickel Solution News, glass container shipments are projected to rise by 2.6 percent in 1988 and by 3 percent during the period from 1988 to 1993.[7]

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[4] Franklin, p. 8.

[5] Gershman, Brickner & Bratton, Inc. Schuylkill County Feasibility Study Final Report, April 1988, p. III-23.

[6] Franklin, p. 15.

The anticipated rise in glass container shipments projected by The Nickel Solution News is based in part on certain consumer preference and marketing trends that are currently active in the packaging industry. A 1987 consumer survey conducted by Packaging magazine indicated that 34.3 percent of those individuals queried preferred glass containers for soft drinks and 59.9 percent preferred glass bottles for beer (as compared to a 30.5 and 34.1 percent preference for metal cans, respectively).[8] In addition, the story of Corona beer provides an interesting example of the effects of packaging on public response to a product.

A few years ago, Corona Extra beer from Mexico was relatively unknown in the United States. By 1987, however, Corona sales had increased dramatically, putting the beer in second place among imported beers (behind Heineken). Corona Extra is shipped in clear, long-necked glass bottles with a distinctive painted label. One of the two U.S. importers of Corona feels that the beer's taste, coupled with its packaging,

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[7] The Nickel Solution News, Vol. 6, No. 2, April 1988, p. 1.

[8] Packaging, The Cahners Magazine for Decision-Makers, 1987.

TABLE A.B-1

GLASS SHIPMENTS
(THOUSANDS OF GROSS)

Type of Container	1986	1985	1984	1983	1982	1981	1980
Narrow-Neck							
Food	27,737[1]	23,770	26,170	28,270	27,658	28,728	28,075
Medicinal and health supplies	15,907	8,710	10,140	9,665	12,393	12,536	12,956
Chemical, household, and industrial		942	1,379	976	1,456	1,718	2,071
Toiletries and cosmetics		5,302	6,566	6,506	8,006	8,489	9,245
Beverage, refillable	62,093	1,553	2,100	3,383	3,729	4,138	4,571
Beverage, nonrefillable		58,532	59,475	59,234	57,291	56,110	53,277
Beer, refillable	87,601	1,870	3,473	2,475	1,899	1,570	1,869
Beer, nonrefillable		81,907	87,323	94,625	105,962	115,768	120,809
Liquor	10,873	11,939	14,015	14,712	13,757	15,365	15,790
Wine	17,157	14,036	221,055	8,916	8,408	8,638	8,784
Total Narrow-Neck	221,368	208,561	221,055	228,762	240,559	253,060	257,447
Wide-Mouth							
Food	60,044	59,935	64,302	60,018	63,372	62,404	61,212
Medicinal and health		2,715	3,150	2,995	3,097	3,274	3,084
Chemical, household, and industrial	4,830[1]	1,015	988	812	1,159	1,122	1,191
Toiletries and cosmetics		595	455	426	659	820	965
Total Wide-Mouth	64,874	64,260	68,895	64,341	68,287	67,620	66,452
Combined Total	286,242	272,821	289,950	293,103	308,346	322,845	326,132

Source: U.S. Department of Commerce.

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[1] Packaging estimates.

accounts for its success.[9] Domestic brewers have noticed the market share increase of the product. Anheuser Busch, for example, is investigating longer-necked bottles. And LaBatt's, a company that recently purchased Rolling Rock beer, has implemented a new packaging strategy that includes a long-neck bottle with silk-screened label to move the beverage into the "prestige beer" market.[10]

Bottles for beer, soft drinks, wine, and liquor plus food bottles and jars are the predominant categories of glass containers. Tables A.B-2 and A.B-3 indicate a breakdown of glass containers and packaging discarded into the municipal waste stream, by type, for selected years from 1960 to 1986 with projections to the year 2000. (Table A.B-2 shows figures in millions of tons, and Table A.B-3 indicates percentages.)

Soft drink--or carbonated beverage--containers often account for more than 5 percent of U.S. household wastes.[11] Until 1975, the international beverage container market was dominated by the refillable glass bottle. By 1981, reflecting the increased demand for convenience products and the economic viability of lightweight aluminum, plastic, and lighter-weight, one-way glass containers, consumers in the United States purchased most carbonated beverages in one-way containers. It is estimated that more than one-half of the glass produced in the United States is made into items with a lifespan of less than 1 year.[12] Most glass containers are disposed of from residences, with bars, taverns, and clubs generating additional quantities.

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[9] Packaging.

[10] Miller, Chaz, Recycling Director, Glass Packaging Institute. Personal communication, April 1988.

[11] Pollack, Cynthia. Mining Urban Wastes: The Potential for Recycling, Worldwatch Paper 76, April 1987, p. 10.

[12] Pollack, p. 10.

TABLE A.B-2

GLASS CONTAINERS AND PACKAGING DISCARDED INTO THE MUNICIPAL WASTE STREAM
1960 TO 2000
(IN MILLIONS OF TONS)[1]

	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1990	1995	2000
Beer and soft drink bottles	1.3	2.5	5.4	5.9	6.0	6.0	5.8	5.4	4.8	4.7	4.5	4.4	4.3	4.1
Wine and liquor bottles	.9	1.4	1.9	2.0	2.4	2.2	2.2	2.2	2.2	2.2	2.1	2.2	2.2	2.1
Food and other bottles and jars	3.4	4.2	4.4	4.4	4.8	4.8	4.8	4.7	4.7	4.3	4.1	4.6	4.5	4.5
Total glass	5.9	8.0	11.7	12.3	13.2	13.3	12.8	12.3	11.7	11.1	10.7	11.2	11.0	10.8

Source: Franklin Associates, Ltd.

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[1] Details may not add to totals because of rounding.

TABLE A.B-3

GLASS CONTAINERS AND PACKAGING DISCARDED INTO THE MUNICIPAL WASTE STREAM
1960 TO 2000
(AS PERCENTAGE OF TOTAL DISCARDS)[1]

	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1990	1995	2000
Beer and soft drink bottles	1.6	2.6	4.8	5.1	4.6	4.6	4.5	4.0	3.5	3.4	3.2	3.0	2.7	2.4
Wine and liquor bottles	1.1	1.5	1.7	1.7	1.9	1.8	1.7	1.6	1.6	1.6	1.5	1.5	1.4	1.2
Food and other bottles and jars	4.2	4.4	3.9	3.8	3.7	3.6	3.7	3.5	3.4	3.1	2.9	3.1	2.8	2.7
Total glass	7.2	8.3	10.4	10.6	10.2	10.1	9.9	9.1	8.5	8.1	7.6	7.5	6.9	6.4

Source: Franklin Associates, Ltd.

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[1] Details may not add up to totals because of rounding.

Refillable glass bottles are approximately 50 percent heavier than disposable bottles and are designed for multiple round trips.[13] Currently, circulated refillable bottles average 10 or 11 round trips. Such containers are experiencing a declining market share in the U.S. packaging industry because they cannot compete economically with one-way bottles or aluminum or plastic containers.[14] The industry trend is away from relatively small bottling plants in nearly every metropolitan area to larger regional plants. The number of bottling plants in the United States was once close to 3,000; now fewer than 300 plants remain.[15]

In April 1978, the Federal Trade Commission ordered Coca-Cola Company, PepsiCo, and others to cease and desist from enforcing contracts that allocated or restricted the territories of franchised bottlers, except for beverages in refillable containers. The orders were appealed in the U.S. Court of Appeals.[16] However, the trend was set in motion, and for the most part, the small-scale bottler has been driven out of the market by larger, high-speed regional plants. Distances that bottled products must be transported have subsequently increased, and the cost associated with the weight differential between refillable glass and other one-way containers is substantial.

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[13] Pollack, p. 21.

[14] Miller, Chaz, April 1988.

[15] Miller, April 1988.

[16] Office of Technology Assessment. Materials and Energy from Municipal Waste: Resource Recovery and Recycling from Municipal Solid Waste and Beverage Container Deposit Legislation, Office of Technology Assessment, Congress of the United States, 1979, p. 233.

Glass containers are fashioned primarily from clear (flint), brown (amber), or green glass. Approximately 65 to 70 percent of all glass containers are made of flint glass, with amber claiming 23 percent of the market, and green holding a 13 percent share.[17]

The main constituent of practically all commercially manufactured glass is sand. Most glass, whether made for containers, flat glass, or drinking glasses, has a somewhat similar chemical composition:

- 70 to 74 percent silica
- 12 to 16 percent sodium oxide
- 5 to 1 percent calcium oxide
- 1 to 3 percent magnesium oxide
- 1 to 3 percent aluminum oxide

Within these wide ranges, specific types of glass will vary in composition to suit a particular product and/or production method. For example, flat glass is similar to container glass except it contains a higher level of magnesium oxide.

Most of the large-scale, commercially produced glass can be classified into three main groups: soda-lime, lead, and borosilicate.

- Soda-Lime Glass: This type of glass is the most common commercially made glass; its chemical and physical properties make it suitable for a wide range of uses. Containers made of soda-lime glass are essentially inert and do not contaminate or affect the taste of the contents. Containers of this type resist chemical attack from aqueous solutions, which allows them to withstand repeated boiling without any significant changes in the glass surface (as with preserving jars). One disadvantage of this glass type is the relatively high thermal expansion that takes place. In general, the higher the content of soda, the poorer the resistance to sudden temperature change (thermal shock).

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[17] Miller, Chaz, Recycling Director, Glass Packaging Institute. Personal communication, May 1988.

- Lead Glass: The use of lead oxide instead of calcium oxide and the replacement of all or most of the sodium oxide with potassium oxide yields what is referred to as lead crystal. Lead crystal contains between 24 and 30 percent lead oxide. Glass containing less than 24 percent lead oxide is known as plain crystal. Lead glass has a high refractive index and a relatively soft surface that is suitable for grinding, cutting, and engraving.

  Lead glass of a slightly different makeup is used in the electrical industry. This type of glass has good insulating properties. Glass with higher lead oxide content (usually 65 percent) has application as shielding glass for radiation because of the ability of the lead to absorb gamma rays.

- Borosilicate Glass: This type of glass is made up primarily of silica (70 to 80 percent) and boric oxide (7 to 13 percent), with smaller amounts of alkalis and aluminum oxide. The comparatively low alkali content produces glass that is chemically durable and more resistant to thermal shock. This glass has extensive application in the chemical industry, for pharmaceutical containers, for high intensity lighting applications, and as glass fibers for textiles and plastic reinforcement. In addition, this type of glass is used to manufacture heat-resistant glass cookware, such as Pyrex.

Many other types of glass exist, with applications ranging from gauge glass for high-pressure steam boilers, to television tubes, to soldering glass, to semiconducting glass. In addition, by deliberately stimulating crystal growth, glass ceramics can be formed that are extremely resistant to thermal shock. Optical glass, designed to meet optical property specifications including refraction and dispersion, can involve a wide variety of glass types. Sealing glass, used for sealing metals for electrical and electronic components, is another application for a range of glass compositions.[18]

The glass industry uses "cullet," or crushed waste glass, as an alternative to and/or a mix with raw materials in processing. In 1970, the glass manufacturing industry purchased 24,000 tons of cullet--a departure from earlier practices of using mostly "in-house" sources (reject batches, production breakage, etc.) for cullet. Since 1970, cullet use from recycled glass has increased to more than 1 million tons each year.[19] Because of the many types of glass and the variance in constituents, cullet use is affected by the cullet's composition. Cullet recovered from flat and blown glass sources is generally not suitable for reuse in glass container plants, though under certain conditions exceptions can be found. Although container cullet may come from several manufacturers, container glass has been harmonized so that it can be used interchangeably in any manufacturer's furnace for new container production.[20]

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[18] Glass Manufacturers Federation. Making Glass, Glass Manufacturers Federation, London, England, 1985, pp. 7-12.

[19] Gershman, Brickner & Bratton, Inc., p. III-23.

[20] Glass Manufacturers Federation, p. 8.

Resource Recycling indicated in the spring of 1987 that the capacity for U.S. glass plants to use cullet was approximately 13 million tons, with the industry using approximately 74 percent of that capacity in 1986.[21]

Even before the energy price hikes of 1973, use of 15 to 20 percent cullet was already standard in some glass plants.[22] The trend in U.S. plants today is toward raising the amount of cullet in each processing batch to 40 percent or more, and the technology exists to run furnaces exclusively on cullet.[23] However, glass container manufacturers must have a guaranteed supply of cullet to increase overall cullet use. It is not practical or economical to run a glass furnace on 90 percent cullet 1 week and 15 percent the next because of changes in cullet availability.

The increased use of cullet is advantageous because cullet melts at a lower temperature, which is reported to assist the melting of the raw materials in the batch and to allow furnaces to run at lower temperatures. These advantages result in energy savings, a reduction in air emissions, and the extension of the life of the furnaces' refractory linings. For each ton of cullet used in manufacturing, approximately 1.2 tons of raw materials are saved. For each 10 percent of cullet mixed into the furnace, a 2 to 5 percent energy savings is gained.[24] Table A.B-4 presents the environmental effects of cullet use in terms of energy savings, air emission reduction, and reduction of mining waste and water use in the manufacturing process.

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[21] Powell, Jerry. "The Year in Review," Resource Recycling, March/April 1987, p. 26.

[22] Pollack, p. 21.

[23] Pennsylvania Glass Recycling Corporation. "Make Recycling a 'Glass' Act," poster.

[24] Pollack, p. 21.

TABLE A.B-4

ENVIRONMENTAL BENEFITS DERIVED FROM SUBSTITUTING SECONDARY MATERIALS FOR VIRGIN RESOURCES (BY PERCENTAGE)

Environmental Benefit	Aluminum	Steel	Paper	Glass
Reduction of				
Energy use	90-97	47-74	23-74	4-32
Air pollution	95	85	74	20
Water pollution	97	76	35	--
Mining wastes	--	97	--	80
Water use	--	40	58	50

Source: Pollack, Cynthia. Mining Urban Wastes: The Potential for Recycling, Worldwatch Paper 76, April 1987.

The value of cullet varies with the color, the quality, and the regional markets available. One major market for cullet is the plants that serve the container industry. In the Pennsylvania/ New Jersey area--a principal glass container manufacturing center of the country--cullet is in high demand. In this area, intermediate markets may pay between $10 and $35 per ton for color-separated cullet, with final markets offering between $40 and $45 per ton.[28]

Factors affecting cullet quality include the degree of color sorting and the amount of contamination present. "Furnace-ready" cullet for container manufacture must meet strict quality standards. Table A.B-5 presents one example of specifications for furnace-ready cullet.

The degree of color sorting probably has the largest impact on cullet marketability. Markets do exist for mixed- color cullet--primarily in the reflective industry and in fiberglass manufacture; however, many more markets, and higher prices, are available for color-sorted cullet. As indicated earlier, most glass packaging is made from flint glass. Some products degrade if exposed to sunlight and require colored packaging. Marketing strategies also affect the container color. Mixing of glass colors in the cullet can produce off-color products that have a negative public perception; most customers will not tolerate color variances in glass containers.[26]

Foreign or "tramp" materials that glass container manufacturing plants fear from postconsumer cullet include metals (such as aluminum caps, steel lids, bottle collars, and light bulb filaments); ceramics (such as cups, dishes, and ovenware); stones and dirt; plate or window glass; heat-resistant glass

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[28] Gershman, Brickner & Bratton, Inc., p. III-24.

[26] Pennsylvania Glass Recycling Corporation, poster.

TABLE A.B-5

SPECIFICATIONS FOR FURNACE-READY CULLET

- Only glass container glass is acceptable.
- Permissible color mix levels are
  - Flint glass

    95 - 100% flint
    0 - 5% amber
    0 - 1% green
    0 - 5% other colors

  - Amber glass

    90 - 100% amber
    0 - 10% flint
    0 - 10% green
    0 - 5% other colors

  - Green glass

    80 - 100% green
    0 - 20% amber
    0 - 15% flint or Georgia green
    0 - 5% other colors

- Glass must be free of excessive moisture.
- Glass must be free of any refractory materials. Grounds for rejection include
  - the presence of pottery, porcelain, china, dinnerware, brick, title, clay, and so forth, larger than 1 inch
  - the presence of more than one particle of any of the materials listed above that is larger than an eighth of an inch, but less than 1 inch in a 200-pound sample (four 5-gallon pails of crushed cullet will weight approximately 200 pounds)
  - the following list that illustrates other examples of refractory particles which will make cullet shipments subject to rejection
    1. the presence of more than two grains or quartzite, sandstone, or sand pebbles larger than U.S. 16 mesh (1.19 mm) per 10 pounds of sample

TABLE A.B-5
(continued)

ii. any clay particles (e.g., kaolin, kaolinite, anauxite) and/or spinel larger than U.S. 20 mesh (.84 mm) or more than 50 particles larger than U.S. 30 mesh (.59 mm) per 10 pounds of sample.

iii. any alumina silicate refractory heavy minerals (e.g., kyanite, mullite, sillimanite, andalusite) larger than U.S. 30 mesh (.59 mm) or more than 10 grains larger than U.S. 40 mesh (.42 mm) per 10 pounds of sample

iv. any alumina refractory heavy minerals (e.g., corundum) larger than U.S. 40 mesh (.42 mm)

v. the presence of zircon, cassiterite, chrome, or similar refractory particles larger than U.S. 60 mesh (.25 mm)

o Glass must be free of metallic fragments and objects. Grounds for rejection include

-- the presence of any metal fragments or objects larger than 1.5 inches (e.g., wide-mouth jar lids, soda cans, food cans, coffee cans, etc.)

-- the presence of more than one metallic particle or object larger than three-eighths of an inch but less than 1.5 inch (e.g., bottle cap size) per 200 pounds of cullet (four 5-gallon pails of crushed cullet will weigh approximately 200 pounds)

-- the presence of more than two metallic particles or objects less than three-eighths of an inch per 50 pounds of cullet

The cullet as received should also be free of wire, staples, nails, bolts, welding rods, and other similar objects.

At present, metallic foil from bottle labels will not be considered as metallic contamination.

o Glass must be free of dirt, gravel, limestone chips, asphalt, concrete, and so forth.

o Glass must be free of excessive amounts of paper, cardboard, wrap, plastics, and so forth.

TABLE A.B-5
(continued)

- Large amounts of glass that is excessively decorated (e.g., painted on labels) must be kept separate.

Source: Brockway, Inc.

(such as Pyrex); and lead-based glass (such as crystal or TV tubes).[27] These contaminants can damage the furnaces and processing equipment as well as result in quality losses for the finished products.

Glass furnaces typically run at temperatures of approximately 2,700°F. Both lead and aluminum melt at these temperatures. Iron, steel, and lead will settle to the bottom of the furnace and potentially damage its refractory lining. Aluminum melts into small balls called "stones" or bubbles called "seeds." These bits of melted aluminum, along with ceramics and stones, can appear in the containers being manufactured, causing both structural imperfections and aesthetic problems.[28] Evidence has shown that the higher the percentage of cullet being used in a batch, the more imperative it is that the cullet be contaminant free.[29]

Some glass plants have beneficiation facilities designed to grind the glass, remove metals, and clean the cullet. As of April 1988, there were an estimated 25 beneficiation machines installed nationwide. By the end of 1988, that number is anticipated to grow to 28.[30] However, this processing equipment generally cannot remove all nonmetallic material and no commercially successful equipment exists that can effectively color sort crushed glass.[31]

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[27] Pennsylvania Glass Recycling Corporation, Pennsylvania Glass Recycling: A How-to Guide, undated, p. 8.

[28] Pennsylvania Glass Recycling Corporation, undated, p. 80.

[29] Miller, May 1988.

[30] Miller, May 1988.

[31] Pennsylvania Glass Recycling Corporation, undated, p. 8.

In addition to glass manufacturing plants and previously cited uses of mixed-color cullet for the production of fiberglass and reflective materials, waste glass cullet can be used in such construction materials as brick, terrazzo, foamed glass products, "Glasphalt," and roadbed construction.

Generally, the value of recovered glass depends on the value of the raw materials being replaced (or the energy being saved) and the possible advantages of replacement. For example, glass waste used in roadbed construction replaces inexpensive aggregate materials such as gravel and slag; therefore, in this application the cullet would have a low value per ton. The value of glass for brickmaking would have a slightly higher value because glass is reported to serve as a fluxing agent, allowing the clay or shale to be fired for less time at lower temperatures. Using waste glass to replace some component of the raw materials required for brickmaking would result not only in a reduction of raw material costs but also in a reduction in energy consumption.[32]

"Glasphalt" is a road surface product in which glass is bound to asphalt by adding lime and other binding agents. The University of Missouri-Rolla has conducted extensive tests on the product, and the advantages of adding glass to bituminous paving material appear to be the excellent wearing and maintenance characteristics and the aesthetic appeal of a shiny surface. The economics, however, seem most favorable to cities that have an immediate "in-town" market--those cities with their own glass recovery and asphalt production systems.[33]

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[32] Duckett, Dr. E. Joseph. "Glass Recovery and Reuse," NCRR Bulletin, National Center for Resource Recovery, Inc., Fall 1978, p. 87.

[33] Miller, April 1988.

With Glasphalt production, as with other uses of cullet, one problem is supply. Approximately 1 billion tons of rock aggregate are used each year in asphalt manufacture in this country--as compared with approximately 11 million tons of total glass being produced.

2. CURRENT WASTE MANAGEMENT PRACTICES

a. Landfilling

The amount of waste glass that is actually landfilled each year is not easily determined. According to the Franklin Associates' study, 11.8 million tons of waste glass remained in the municipal waste stream in 1986 after materials recovery but before energy recovery; this figure accounted for 8.4 percent of the total net discards.[34] However, the portion of the recovered glass that ultimately reaches the landfill, or how much glass remains in the waste stream after energy recovery, is unknown.

The effects of glass as a component of MSW sent to an incinerator or waste-to-energy facility are clearly negative. Glass is noncombustible, is abrasive to the processing equipment, and slags in the furnaces. Theoretically, the majority of recovered glass--glass that has been separated from the waste stream--could be recycled if properly processed. In practice, however, a great deal of the glass that is recovered in refuse-derived fuel (RDF) processing, for example, is never reused or introduced to the point of remanufacture because of quality and contamination problems and/or unfavorable economics.

There are many ways to recover cullet from MSW. The source-separation approach is discussed more fully later. There are also several systems in which mixed MSW is mechanically processed for cullet recovery. Froth flotation and optical sorting are two techniques that have shown limited applicability for the recovery of usable cullet.

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[34] Recovery rates do not include fiberglass or glass beads.

Froth flotation is a minerals-processing technique that has been adapted for use in waste glass recovery. Based on the tendency for hydrophobic particles to accumulate at the air/water interface of an aqueous system, froth flotation treats an aqueous mixture of glass and nonglass particles with a compound that selectively adsorbs onto the glass surface, and the treated-glass particles become hydrophobic. When air is blown through the mixture, the treated glass rises with the air bubbles to form a froth on the surface of the water. The froth is skimmed off the top of the water to recover glass; the tailings (primarily nonglass particles) remain as a sediment at the bottom.[35]

To date, no practical method has been developed for color-sorting of froth-floated cullet. The cullet particles are too small to be optically color-sorted with commercially available equipment. Theoretically, large particles of glass could be optically color-sorted first, then crushed and froth-floated. Under present market conditions, however, such a procedure is not considered economically viable.[36]

In RDF production, it is especially important to remove glass to maintain the quality of the fuel product. The Raytheon-operated Delaware Solid Waste Authority MSW Reclamation Project is an extensive materials separation facility that also produces fluff RDF. This plant does operate a froth flotation unit for separating glass. The ground mixed-color glass that results from the processing is sold to Owens-Corning Fiberglass in New Jersey for use as feedstock in the manufacture of fiberglass insulation.

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[35] Duckett, p. 90.

[36] Duckett, p. 90.

However, the economics of the glass recovery operation are not good. Raytheon plans to introduce a two-stage screening process that will remove more organics and submit less-contaminated material to the froth flotation unit. It is hoped that this additional screening will result in a higher quality of recovered cullet and will have a positive effect on the overall economics of the glass recovery operation.

Delaware's enactment of "Bottle Bill" legislation resulted in a reduced amount of glass in the MSW that enters the Delaware plant. The law also affected the economics of Raytheon's glass recovery efforts. When the plant's system was designed, glass was expected to make up 12.1 percent of the MSW received. As of October 1986, however, glass accounted for only 5.4 percent of the MSW.[37] In fiscal year 1987, the plant processed 224,051 tons of MSW; of that input, 737 tons of glass were recovered.[38]

Two other plants were constructed with commercial quality glass recovery systems that included froth flotation units. The Recovery I Project in New Orleans was an RDF plant that recovered cullet that successfully met glass container industry specifications for use in the manufacture of amber container glass. Though the recovered product was mixed-color cullet, the market was able to use the material in amber glass production by regulating the batch fractions. Monroe County, New York, also operated an RDF plant that included a froth flotation operation. However, the glass separation process never became fully operational at this plant.[39]

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[37] Roderique, John, and Darlene Snow. Memorandum to the staff of Gershman, Brickner & Bratton, Inc., regarding site visit to Raytheon Service Company, October 30, 1986.

[38] Vasaturo, Steve, of Raytheon Service Company. Personal communication, May 1988.

[39] Bernheisel, J. Frank, GBB. Personal communication, May 1988.

The second major mechanical-processing technique applied to recovering the glass fraction of MSW is optical scanning. This approach involves sorting opaque (mostly nonglass) particles from transparent ones and then sorting the transparent particles by color. The basis of optical sorting is photocells, which are used to measure the intensity of light transmission through MSW particles and to trigger the separation of one class of particle from another. The approach has been reported to be successful in making a split between flint and nonflint particles.[40] However, the sophisticated equipment is very expensive, and commercial application has been largely unsuccessful in meeting glass container industry specifications for either color separation or refractory contamination.[41] At present, the systems are considered impractical for large-scale use.

b. Recycling

Glass, which has been called 100 percent recyclable, is considered a "closed loop" recyclable--which means that for each pound of glass recycled, a new pound of glass could be generated. According to the Glass Packaging Institute's Director of Recycling, the exact amount of glass being recycled is not yet known.[42] It does seem clear, however, that recycling rates for glass (and aluminum and paper products) are increasing in many industrialized countries. Table A.B-6 shows the 1985 glass recovery rates for several countries.

It has been suggested that minimum 50 percent recovery rate for glass is feasible and the Organization for Economic Co-operation and Development estimates that 90 percent of waste

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[40] Duckett, pp. 91-92.

[41] Duckett, pp. 91-92.

[42] Miller, May 1988.

TABLE A.B-6

RECOVERY RATES FOR ALUMINUM, PAPER, AND GLASS IN SELECTED COUNTRIES
1985
(BY PERCENTAGE)

Country	Aluminum[1]	Paper[2]	Glass[3]
Netherlands	40	46	53
Italy	36	30[4]	25
West Germany	34	40	39
Japan	32	51[4]	17[2]
United States	28	27	10
France	25	34	26
United Kingdom	23	29	12
Austria	22	44	38
Switzerland	21	43	46
Sweden	18	42	20

Source: Pollack, Cynthia. Mining Urban Wastes: The Potential for Recycling, Worldwatch Paper 76, April 1987.

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[1] Includes industrial recycling.

[2] Data for 1984.

[3] In Europe most of the glass is refillable; recovery rates apply only to nonrefillables.

[4] Data for 1983

glass could be made available for recovery.[43] However, specification requirements make realization of these goals unlikely.

The economics of recycling primarily depend on the costs of alternative disposal methods, the markets for recovered products, and the costs associated with running the recycling program. Recycling is a cost-effective disposal alternative as long as it requires fewer subsidies than either landfilling or incineration.[44] The economics of glass recycling must be viewed in terms of "avoided costs"--the costs that are saved by not landfilling the glass fraction of MSW. As landfill costs escalate and the costs associated with pollution control for incineration facilities continue to rise, the appeal of recycling is projected to increase.

Removing postconsumer glass from the waste stream decreases the weight of the MSW. Most tipping fees at U.S. landfills are figured by weight, rather than by volume, so a high glass content can have an impact on total disposal costs.[45] According to one consultant, curbside collection programs generally cost more to operate than the revenues they generate; however, as a waste management tool, recycling is often the least expensive handling alternative. Almost all materials are worth more when recycled as a cost-avoidance mechanism than their value on the open market.[46]

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[43] Pollack, p. 27.

[44] Pollack, p. 27.

[45] Trunick, Perry A. "Low Public Awareness Limits Supplies of Recycled Glass," Recycling Today, April 1988, p. 62.

[46] Pollack, p. 28.

c. Recycling of Residentially Generated Glass

Encouraging consumer participation and establishing firm markets for the recovered materials are two elements that are critical to a recycling program's effectiveness. Consumer participation involves source separation of glass (usually in addition to other target materials) from residential MSW.

Source separation programs, which account for essentially all of the recovery of postconsumer container glass in the United States, can take may forms.[47] The following are among the more common approaches for collecting source-separated residentially generated recyclables.

(1) Voluntary Drop-Off Centers

Under this approach, individuals deliver their source-separated glass to neighborhood recycling centers. Often these centers are operated to benefit a charity or not-for-profit organization and are staffed by volunteers. Under some scenarios, bins are provided for different colored glass containers and the color sorting is accomplished by the individuals making the deliveries. Under other schemes, the center may accept commingled colors of glass and have the center's staff perform manual color sorting (and sometimes removal of metal, such as the aluminum rings from bottle necks).

(2) "Bottle Bank" Systems

The "Bottle Bank" system, modeled after similar systems in Switzerland, Germany, and France, was adopted by the glass container industry in Britain in 1977. The approach involves individuals depositing their waste glass in special containers that are located conveniently in centers of neighborhood activity, such as shopping center parking lots. The British program includes separate containers for flint, green, and amber glass; each container is painted representatively (white for flint, green for green, and brown for amber). In the British system, the glass industry collects the Bottle Bank discards and processes the glass through cullet treatment plants to remove metals and contaminants.

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[47] Duckett, p. 90.

"Igloo" containers are one version of the British Bottle Banks seen in America. These dome-shaped fiberglass bins are also placed at neighborhood focal points. Igloos may be designated for separate color glass containers or for commingled colors. The shape of these Igloo containers is not associated with other trash receptacles, and openings have been designated to discourage dumping of nonglass items.

The Igloo system typically operates to benefit civic, charity, or community organizations. The Igloos are located on the premises of these organizations and proceeds from collected glass go to the host group.

(3) The "Cash-for-Trash" Approach

The "cash for trash" scenario is based on the idea that individuals are more likely to participate in recycling programs if there is a direct financial incentive. The system involves buyback centers where consumers can take their waste glass containers and receive cash back. The Beverage Industry Recycling Program began a buyback operation for glass containers in Arizona in 1971; by the late 1970's, the program was offering 1 cent for each bottle returned. Startup capital for the buyback centers was provided by the beverage bottlers and wholesalers.[48]

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[48] Duckett, p. 89.

A study conducted in 1985 for Owens-Illinois, Inc., and for the Santa Barbara 2000 Study concluded that the effectiveness of buyback centers would be enhanced for residentially generated glass waste by higher buyback rates--3 to 5 cents per container.[49] The study cited previous research that indicated that the average householder participating in source separation spent a total of 4.6 minutes per week cleaning, color-sorting, and removing contaminants from recyclable glass (three to five containers on average). Based on case-study data on revenue received from collection centers, the monetary return on household preparation effort was computed as 4 cents per minute. The monetary return on time invested was higher for both aluminum and paper.[50]

(4) Municipally Collected Programs

Under municipally collected systems, individuals are required to keep their glass (and often metal, paper, and plastic) wastes separate from the rest of their garbage. The separated wastes are then placed curbside for collection. Depending on the collection strategy used by the community, the source-separated recyclables would be collected in designated containers (either supplied or mandated by the collecting agency) on the same day as regular trash pickup or on separate days designated as recyclables pickup days. The waste stream characterization, population density of the community, processing and storage capabilities of the receiving organization, and equipment and labor availability of the hauler would all contribute to the determination of how often the recyclables are collected. The collection vehicles for the recyclables can be compartmentalized to handle each type of recyclable or can be designed to accept commingled recyclables that are sorted at a processing facility.

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[49] Snow, Darlene, and Edwards Ballina. Glass Recycling: Opportunities and Constraints, prepared for Owens-Illinois, Inc., and for the Santa Barbara 2000 Study, Santa Barbara, California, August 1985.

[50] Stearns, Conrad & Schmidt Consulting Engineers. "Analysis of Source Separate Collection of Recyclable Solid Waste," 1974.

(5) Intermediate Processing Facilities

These centers are designed to receive either separated or commingled recyclables and to clean and process them to market specifications. Centers can range in complexity from relatively labor-intensive sorting assembly lines to more mechanized systems that provide mechanical sorting and beneficiation. The goal of these facilities with regard to glass is generally to produce color-sorted, furnace-ready cullet for sale to the glass industry. Some mixed-color cullet may also be produced for sale to lower-grade markets.

The glass container industry is an advocate not only of legislatively mandated recycling efforts, but also of multimaterial collection facilities. Owens-Illinois (O-I), for example, buys cullet in all 14 of its glass manufacturing plants and is using recycled glass equal to 56.1 percent of all the soft drink and beer containers that it produces.[81] O-I supports multimaterial collection centers as a way to effectively increase the amount of high-quality cullet available. This support comes through public information campaigns and programs such as interest-free loans. If a recycling center can supply 2,000 tons per year of glass that meets O-I's specifications, the center may be eligible to receive an interest-free loan to purchase glass processing equipment. (Note: Other restrictions do apply.)[82]

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[81] Owens-Illinois Glass Container Division. The Value of Glass, 1987.

[82] Trunick, p. 64.

(6) Mandated Source-Separation Programs

There is a growing trend in many states, counties, and municipalities in the United States toward mandatory source-separation and recycling legislation. The feeling of proponents of such legislation is that mandated recycling guarantees participation of individuals in the overall solid waste management plant of their locale. A preferred collection strategy and processing approach may be stated as part of the legislation. Other legislation may dictate the recycling goals, but may leave the details of how to achieve these goals to the implementing communities. Implementation can be accomplished through municipally sponsored curbside collection, voluntary drop-off centers, or some combination of the previously described alternatives.

In April 1987, New Jersey passed a Mandatory Statewide Source Separation and Recycling Act. The law required that each county must appoint a district recycling coordinator; identify leaves and at least three other recyclables to be the designated recyclables for the district; and designate a strategy for collecting, marketing, and depositing of the source-separated materials in each municipality. The law further provided that the counties must solicit proposals for processing and marketing the materials and must enter into contracts on behalf of the municipalities. The municipalities, on the other hand, were charged with the designating a local recycling director, providing a recyclables collection system, and adopting ordinances requiring generators of MSW to source separate the municipality's designated recyclable materials.

Other legislation may dictate the recycling goals but leave the details of how to achieve these goals to the implementing communities. Implementation can be accomplished through municipally sponsored curbside collection, voluntary drop-off centers, or some combination of the previously described alternatives.

(7) Beverage Container Deposit Legislation ("Bottle Bills")

This legislation, which has all but replaced the once-common bottler-promoted deposit programs, requires consumers to pay a deposit on beverage containers; the deposit is redeemed when the containers are returned to the retailer. Nine U.S. states have passed returnable container deposit laws, and 23 other states are reportedly contemplating enacting similar legislation. The advantages of the legislation include the ease of color separation of the returned containers, a reduction in litter resulting from glass containers, and an increased awareness of recycling behavior.[63]

However, the effects of such legislation on the glass industry appear to be negative. While the laws strive to divert glass from landfills and encourage recycling, they simultaneously encourage a shift to plastic at the expense of glass in the marketplace. Most supermarkets and convenience stores do not have adequate on-premises storage space to handle returned bottles, which require special handling. In addition and for similar reasons, consumers in Bottle Bill states seem to prefer the more convenient handling of plastic and aluminum.

A recent study indicated that the effect of container deposit legislation on recycling is uncertain. The study cites up to 90 percent of discarded glass containers have been diverted from the MSW stream in the target states at the result of the legislation. However, the demand for glass is reduced by the laws and the markets in certain areas have been flooded with certain types of cullet.[84],[85] In New York City, for example, green cullet has become increasingly available--primarily through the recovery of imported beer bottles--and current supply levels exceed market demand for green glass. This situation is specific to New York City; because of the City's unusual demographics and market conditions, it may not be advisable to assume a national, or even a regional, trend from these data.

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[63] U.S. Environmental Protection Agency. Municipal Waste Combustion Study: Recycling of Solid Waste, June 1987, pp. 4-5.

Statewide in New York, the container deposit legislation resulted in a market-share increase from 5.1 percent to 6 percent for refillable glass bottles in 1984. This increase was not enough, however, to offset the market-share loss sustained by nonrefillable bottles, which fell from 27.9 percent to 18.9 percent (1984).[86]

Some reviewers of Bottle Bill legislation feel that the recycling of glass is initially hindered by the initiation of such legislation, because glass markets in the region become flooded and prices decrease significantly.[87] Others suggest that cullet markets for green glass tend to flood under Bottle Bill conditions, while flint markets remain relatively constant. Regional differences in the effects of container deposit legislation have also been noted. The West Coast, for example, does not appear to have experienced the same market constraints and shifts in container purchases that have been noted on the East Coast under Bottle Bill conditions.

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[84] New York State Legislative Commission on Solid Waste Management. The Economics of Recycling Municipal Waste: Background Analysis and Policy Approaches for the State and Local Governments, a staff report to the New York State Legislative Commission on Solid Waste Management, 1986, p. 30.

[85] U.S. Environmental Protection Agency, pp. 4-5.

[86] New York State Legislative Commission on Solid Waste Management, p. 30.

[87] Nosenchuck, Norman H., New York State Department of Environmental Conservation, Albany. Personal communication, May 1988.

Recyclers tend to disapprove of Bottle Bills because they remove secondary commodities such as glass, for which proven recycling technologies exist, from the waste stream without offering a substantial solid waste benefit. In addition, the cost of excluding beverage containers from a mandatory curbside collection program can be significant.[88]

(8) Other Legislative Approaches

In Ontario, Canada, regulations were instituted in 1985 that tie the market shares of refillable and disposable soft drink containers to the use of deposits. The refillable bottle market share of 40 percent is safeguarded, and all one-way containers are required to achieve a 50 percent minimum recycling rate within 3 years after their appearance on the market. Failure to achieve the mandated recycling rate would result in the imposition of a deposit equal to the deposit on similarly sized refillable containers.[89]

Deposits on beverage containers are also used in the Netherlands, Scandinavia, the Soviet Union, and parts of Canada, Australia, and Japan--in addition to many developing nations. In West Germany and Switzerland, the government has the discretionary ability to require deposits on one-way packages.

d. Recycling of Commercially Generated Glass

Bars, restaurants, and hotels also contribute heavily to the fraction of MSW composed of container glass. For these commercial establishments, the avoided disposal costs and the revenues associated with glass recycling could be significant. In California, the California Glass Recycling Corporation (CGRC) is sponsoring the Phoenix Project. Within this project, CGRC and independent service contractors provide commercial eating and drinking establishments with exterior bins for color-sorted glass. The program, which began in March 1987, generates between 2,000 and 14,000 pounds of recyclable beverage-container glass each month.[60]

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[88] New York State Legislative Commission on Solid Waste Management, p. 30.

[89] Pollack, p. 33.

It is also possible to recycle noncontainer glass, such as plate and flat glass. R2B2, a recycling program in the Bronx, New York, successfully recycles both preconsumer and postconsumer "pane" or flat glass. Preconsumer flat glass (rejects, breakage, etc.) generally contains more lead than container glass. However, whether the lead difference is critical depends on the application and the particular market. For example, the R2B2 Director of Operations indicated that the glass container industry does purchase quantities of preconsumer flat glass for container manufacture. Apparently, a small percentage of the flat glass is acceptable as cullet for container glass, depending on the batch mix. Generally, there is reluctance for container manufacturers to purchase noncontainer cullet unless the chemical composition of the cullet is known and the source is proven to be reliable.[61]

Fiberglass operations and other manufacturing processes, such as tile manufacture, are also possible markets for this flat glass cullet. In addition to these applications, there is an export market for the preconsumer windowpane. The R2B2 spokesman indicated that the end use of this exported material is unknown.[62]

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[60] Glass Packaging Institute. Recycling: The Need Is Clear--A Report on the Glass Container Industry's State Recycling Programs, 1987, p. 3.

[61] Miller, May 1988.

Postconsumer pane glass is suitable for use in Glasphalt production. Glasphalt specifications are less sensitive to the presence of contaminants than many other waste glass markets. Putty and paint from postconsumer window glass would present problems in fiberglass furnaces, for example. However, depending on the batch fraction composed of waste glass, the presence of these contaminants and others (ceramics, headlight glass, etc.) does not appear to cause processing or quality problems for Glasphalt. In fact, according to the R2B2 spokesman, Glasphalt made with postconsumer pane glass performs better on stability (core sample) tests than the same material manufactured with waste bottle glass.

e. Recycling of Industrially Derived Glass

Industrial-derived cullet is another important source for intermediate glass processing.[63] Most of the sources of industrial glass are business that make, shape, or treat the glass. These glass industries use their own in-house, or "runaround," scrap. However, while color sorting and contaminant removal are the major impediments to cullet use in glass container manufacturing, separation by product type seems to be the key issue for industrial-derived cullet. If runaround scrap becomes mixed with other glass of different constituents, it is not useful to the glassmaker.

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[62] Schedler, Michael, Director of Operations, R2B2, Bronx, New York. Personal communication, May 1988.

[63] Weiss, David B. "Intermediate Glass Processing," NCRR Bulletin, National Center for Resource Recovery, Inc., September 1987, p. 54.

According to the Bassichis Company, a business that focuses its recycling efforts on industrial glass, processing industrial cullet for markets presents two major stumbling blocks: the level of processing required to achieve the proper grade of material to meet each market's specifications, and the issue of chemistry. The chemistry of automobile plate glass (which is made from a lamination of glass and plastic and often includes tinting) is different from clear plate, architectural plate, and coated plate. Each of the product types has distinctive melting properties that must be taken into account.[64]

Another source of industrial cullet, beyond the runaround scrap, is transition glass. During changeovers on production lines from one type of glass to another, transition glass is produced. To change from one type of glass to another, manufacturers do not drain out the old material and begin with new feedstocks. The changeover generally involves a flow from one material to another, with the output representing a mixture of both batches. When the changeover is complete and the product is pure, the transition glass is scrapped.[65]

f. Selected State Recycling Programs

In response to the waste management crisis and the need to promote the recyclability of glass in comparison to plastics, the glass packaging industry has begun implementation of statewide glass recycling programs.[66]

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[64] Trunick, p. 60.

[65] Trunick, p. 61.

[66] Descriptions of statewide glass recycling efforts are based on information provided in Glass Packaging Institute, Recycling: The Need Is Clear--A Report on the Glass Container Industry's State Recycling Programs, 1987.

(1) California

Effective September 1, 1987, the California Beverage Container Recycling and Litter Reduction Act guarantees consumers no less than 1 cent for each recycled beverage container. The law mandates a 65 percent recycling rate. To carry out this aggressive goal, the act mandates establishing certified recycling centers within each of the state's 2,000-plus "convenience zones" (defined as the area within a half-mile radius of any grocery store doing more than $2 million worth of business each year).

The CGRC, an effort sponsored in California by the glass industry, has developed comprehensive consumer and commercial glass recycling programs, has placed more than 500 glass collection banks throughout the state, and has promoted glass recycling through public information activities and technical assistance plans.

The Phoenix Program, aimed at recovering postconsumer glass containers from the state's bars, restaurants, and hotels, is one example of the CGRC's programming. Participating establishments are reportedly generating between 2,000 and 14,000 pounds of glass each month and collecting approximately $20 per ton for their efforts.

(2) Florida

Florida is experiencing a boom of commercial and population growth that has sparked growing concern over the management of the state's natural resources. Recycling glass, as one tool for limiting dependence on landfilling and reducing the raw material and energy needs of glass manufacturing, has received increased attention from both residents and State government.

The Florida Glass Recycling Program was established in the spring of 1986 to promote glass recycling activities statewide. The efforts of this program have been supported by the state's glass manufacturers and include educational programs directed at school-aged children as a way to broaden the base of support for voluntary glass recycling initiatives. Theme-related recycling centers have also been instituted; for example, Goodwill Industries opened a recycling center with an agricultural theme in Lakeland, Florida, in 1985. In less than 1 year of operation, the Goodwill Recycling Market collected over 2 million tons of glass. Goodwill plans to build and run as many as 15 additional centers throughout the state.

The Florida Business and Industry Recycling Program statistics indicate that glass collections in the state rose by 19 percent in 1986, boosted by 57 recycling organizations. The program further reported that the glass plants in Florida bought 53.5 million pounds of postconsumer glass containers in 1986 (as opposed to 45 million pounds in 1985). Revenues paid to recyclers for the collected glass were indicated to be $1.6 million in 1986.

(3) Indiana

In summer 1987, the Indiana Glass Recycling Association was formed, backed by five major glass manufacturing companies in the state. The Association is trying to increase the number of recycling centers throughout Indiana that accept glass through the provision of educational and promotional materials. Plans are in effect to distribute the "Great Glass Caper" school curriculum to fourth-grade classes. The teaching kit explains the basics of glass recycling in an effort to promote interest and participation from future consumers.

(4) Mid-Atlantic Glass Recycling Program (MAGRP)

The Mid-Atlantic Glass Recycling Program, established in 1987, sponsors glass recycling efforts in Maryland, Virginia, and the District of Columbia.

In 1987, 13 Maryland glass buyback centers and 32 voluntary drop-off sites were reported. MAGRP is dedicated to increased public awareness of and participation in the existing glass recycling activities. In addition to the buyback and donation centers, Maryland has recently established a pilot curbside collection program in Anne Arundel County (home of the state's capital, Annapolis). Glass containers will be among the target recyclables collected. This program is being conducted in response to the recent enactment of State legislation that mandates municipal solid waste reduction through source separation and recycling.

In Virginia, 29 buyback centers and 19 drop-off sites for donated glass were in operation in 1987. Negotiations are being made to increase these facilities and promotional flyers, press releases, and related educational material have been developed to increase public awareness of the benefits of glass recycling.

In Washington, D.C., MAGRP began "Operation Igloo--Glass Recycling." The effort involved placing glass donation drop-off sites at local churches. The revenues generated from the collected glass benefit the host churches. The program was enthusiastically received by the Council of Churches of Greater Washington.

(5) North Carolina and South Carolina

In June 1986 the Carolina Glass Recycling Program (CGRP) was formed. At that time, only nine recyclers in the two-state region accepted recycled glass. However, the climate for glass recycling was good--some major glass manufacturers were based in the Carolinas, many environmental groups were already bringing the landfill crisis to the forefront of public attention, and many private recycling businesses did exist that handled metal and paper. Community and corporate support for glass recycling was enlisted and a glass recycling network was established that included more than 65 organizations in 1987.

When CGRP was established, the number of glass bottles and jars being recycled in the region each month totaled approximately 1 million. In 1987, that figure was up to 8 million. Surveys conducted in May and November 1986 indicated that public awareness that glass could be recycled increased 10 percent, and 12 percent more of the people surveyed in November indicated glass as their preferred packaging.

(6) Pennsylvania

Pennsylvania has the second largest number of glass container manufacturing plants in the United States (second to California). This ready market, combined with skyrocketing waste disposal costs, spurred the development of the Pennsylvania Glass Recycling Corporation (PGRC) in late 1985.

In May 1987, Delaware County became the first Pennsylvania area to implement the Igloo system. As an experimental effort sponsored by the Pennsylvania Department of Natural Resources, PGRC, and Delaware County, the program placed Igloo containers at 22 collection sites. In December 1987, the number of Igloos had risen to 23 and 81.9 tons of cullet were collected. By spring 1988, 48 additional Igloos had been purchased, encouraged by the recovery rates. PGRC has been instrumental in encouraging widespread participation in Igloo recycling programs.

Theme-based recycling centers have also been developed as part of PGRC's efforts. Goodwill Industries operates an aviation theme center in Harrisburg, and Glenshaw Glass opened a "Recycling Farm" buyback center in the Pittsburgh area. Other buyback centers, such as Tote-M-Beck Recycling Center in Lancaster, Pennsylvania, have been encouraged by PGRC. From summer 1986 to winter 1987, the Tote-M-Back facility has purchased the equivalent of 1.1 million 12-ounce bottles from the public. PGRC was also involved in bringing a glass processing facility to the City of Chester. At the processing facility, glass is cleaned, crushed, and checked for contaminants.

(7) Wisconsin

The Wisconsin Glass Recycling Program was started in April 1987. The program established a cooperative arrangement between glass manufacturing plants and recycling organizations to guarantee a market for the recycled glass. Recycling organizations have been encouraged to add glass to their list of materials accepted. The "Great Glass Caper" school curriculum has been distributed throughout the state.

(8) Other State Glass Recycling Programs

Other state glass recycling programs are being considered for Louisiana, Missouri, New Mexico, Colorado, Oklahoma, Texas, Kansas, and Arkansas. It has been projected that 27 states will face a solid waste crisis within the next 10 years and that glass recycling initiatives can help to abate at least a portion of the crisis.

g. International Glass Recycling

The international approach to recycling glass is varied. As previously described, Britain has been operating successful

Bottle Banks for 10 years. Table A.B-7 indicates the amount of glass recycled in 1984 for Great Britain and several European countries. The average population served by each volunteer drop-off site is listed to show that increases in the number of available drop-off sites probably result in increased levels of consumer participation.

TABLE A.B-7

1984 COMPARISON OF GLASS COLLECTED FOR RECYCLING IN EUROPEAN COUNTRIES RELATED TO AVAILABILITY OF SITES AND GLASS CONTAINER USAGE

Country	Population per Site	Glass Recycled Kg/head	Glass Container Usage
Switzerland	1,876	21.7	43.8
Germany	1,671	15.0	47.6
Netherlands	1,750	13.9	31.0
France	2,067	9.4	46.0
Italy	2,741	5.5-8.0	31.5
Great Britain	16,142	2.2	31.75

The implication behind these figures is that more Bottle Banks in the United Kingdom will result in more glass for recycling.

Source: FEVE Annual Survey of European Glass Recycling 1984, taken from Expanding Glass Recycling - A LARAC Guide, Local Authority Recycling Advisory Committee (LARAC), London, England, January 1987.

West Germany also uses the volunteer drop-off approach to glass recycling. Across the country, 35,000 bottle collection centers have been established. In 1985, the glass container manufacturing industry purchased nearly 1 million tons of domestic cullet and imported another 90,000 tons of scrap glass.[67]

Switzerland is one of the world's largest per capita users of glass. On the average, approximately 44 percent of the glass consumed in Switzerland is recycled. Here, as elsewhere, the demand is greatest for clear and amber cullet.[68]

Sweden is another world leader in glass recycling and reuse. Beginning in 1970, Swedish glassmakers turned their focus to municipal recovery projects. By 1980 the recycling industry began using Igloo-type containers and recycling efforts skyrocketed. By the mid-1980's, over 200 local governments were involved. A unique partnership of public and private interests, Svensk GlasAtervinning AB, was established in 1986. To secure additional amounts of cullet, the firm is working with the Swedish environmental protection agency and various environmental and beautification programs. Part of the company's profits will fund research; in addition, some portion of profits will be allocated to scrap container suppliers in the form of higher prices. The Swedish glass industry's purchases of cullet have risen from 21,000 tons per year in 1983 to an estimated 40,000 tons in 1987.[69]

In France, the Government required in 1979 that beverage containers in household waste be reduced 40 percent and that the amount of energy used to produce each 100 liters of beverage packaged be cut back 12 percent by 1984. The Government left the specific strategies for reduction up to the target industries. However, enforcement problems hindered the program's effectiveness.[10]

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[67] Pollack, p. 34.

[68] Pollack, p. 34.

[69] Powell, Jerry. "Glass Container Recycling in Sweden," Resource Recycling, March/April 1988, pp. 26-27.

The Japanese do not maintain aggregate data on recycling (because they consider reusable materials to be resources and not wastes). However, the following are among the identified trends regarding the handling of postconsumer glass in Japan:

- In 1983, 66 percent of the bottles were used an average of three times.
- In Japan, 95 percent of the beer and 2-liter sake bottles are recovered and reused up to 20 times.
- In 1984, 42 percent cullet was used in glass bottle manufacturing.
- One-way glass containers, such as medicine bottles, are landfilled (not reused or incinerated).[11]

Tables A.B-8 and A.B-9 indicate the proportion of bottles reused (not cullet) and the percentage of glass recovered by region. Table A.B-10 illustrates the bottle output and quantity of cullet used in Japan for 1980 through 1984.

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[10] Pollack, p. 45.

[11] Hershkowitz, Allen, and Eugene Salerni. Garbage Management in Japan: Leading the Way, INFORM, Inc. 1987, pp. 40-46.

TABLE A.B-8

PROPORTION OF COMPLETE BOTTLES REUSED IN JAPAN
(FY 1983)

Items	Quantity Used (1,000s)	Quantity Collected (1,000s)	Percentage of Bottles Reused	Average Number of Times Reused
2-liter sake bottles	7,830	7,440	95	20.0
Beer bottle	608,970	578,520	95	20.0
Juice bottle	274,000	250,890	91	11.1
1.8-liter sake bottle	122,250	102,690	84	6.3
Soda bottle	332,000	258,400	78	4.5
Yogurt	11,300	2,030	18	1.2
Soy sauce	32,500	5,530	17	1.2
Domestic whiskey bottle	61,810	8,040	13	1.1
Middle- and small-size sake bottles	76,400	8,300	11	1.1
Medicinal drink bottle	281,500	0	0	1.0
Instant coffee bottle	31,980	0	0	1.0
Imported whiskey bottle	7,800	0	0	1.0
Total	1,848,440	1,221,840	66	2.9

Source: Japan Bottles Association

TABLE A.B-9

GLASS RECOVERY BY REGION IN JAPAN
(1983)

Regions	Number of Cities Surveyed	Cities Responding		Percent Recovered	
		Number	Percent	Empty Bottles	Cullet
Hokkaido	32	23	(71.9)	33.3	0.0
Tohoku	64	49	(76.6)	58.8	29.4
Kanto	152	97	(63.8)	68.7	62.7
Hokuriku	44	34	(77.3)	11.1	0.0
Chubu/Tokai	101	70	(69.3)	53.7	65.9
Kinki	86	57	(66.3)	37.9	65.5
Chugoku	48	34	(70.8)	55.6	33.3
Shikoku	30	20	(66.7)	55.6	44.4
Kyushu/Okinawa	90	60	(66.7)	44.4	22.2
Total	647	444	(68.6)	54.0	51.5

Source: Japan Bottlers Association.

TABLE A.B-10

OUTPUT OF BOTTLES AND QUANTITY OF CULLET USED IN JAPAN

	1980	1981	1982	1983	1984
Output of bottles (1,000t)	1,957	1,740	1,907	2,147	2,240
Quantity of cullet used (1,000t)	695	678	801	888	949
Percentage of cullet used	35.5	39.0	42.0	41.3	42.4

Source: Japan Bottlers Association.

t = metric tonne.

h. Source Reduction

In Norway and Denmark, the approach to glass recycling extends to source reduction. Fewer than 20 different returnable packages for beer and carbonated beverages are allowed on the market.

Some source-reduction proponents have suggested that waste volumes will not be reduced to any substantial degree by back-end measures until products and packaging are designed less for convenience and more for durability, reuse, and recycling. Suggestions have been made that standardized refillable containers--similar to traditionally shaped wine bottles that vary only in labeling--should be produced so that multiple product manufacturers could use the bottles interchangeably.[72]

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[72] Pollack.

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TABLE OF CONTENTS

APPENDIX A

C. PLASTIC

Page

1. U.S. PRODUCTION OF PLASTICS A.C-2
    a. Current Output of the Industry A.C-2
    b. Markets for Plastic Products A.C-4
    c. Production Inputs A.C-8

2. WASTE MANAGEMENT OF PLASTICS A.C-9
    a. Quantity of Disposed Plastics A.C-9
    b. Incineration of Plastics A.C-14
    c. Recycling A.C-15
    d. Proposals and Legislation A.C-23
    e. Research and Development A.C-24

3.CONCLUSION A.C-26

REFERENCES A.C-28

APPENDIX A

MAJOR WASTE STREAM COMPONENTS

C. PLASTIC

This appendix characterizes the growing U.S. plastics industry and the management of plastic waste material in this country. The plastics industry has undergone a period of rapid and sustained growth over the past 30 years and is currently the fastest growing segment of the over-$200 billion chemical industry. In 1985, 47 billion pounds of plastics were produced in the United States with 83 percent, or 39 billion pounds, consumed by domestic markets. Of the 39 billion pounds, 33 percent was for packaging, 26 percent for building and construction, and 10 percent for consumer products.[1] In that year, the plastic industry contributed 1.8 percent to the GNP, used 0.5 percent of the total labor force, and employed 1.0 percent of all manufacturing employees.[2,3]

Packaging is one of the fastest growing markets for plastics, and the plastic packaging industry projects that it will increase its output 70 percent to 75 percent by the year 2000. Because packaged products have become part of the daily lives of millions of Americans, consumer demand for packaged products has fueled much of the growth. As the industry improves the types of plastics available, this demand is expected to rise even higher.

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[1] Rauch Associates, Inc. The Rauch Guide to the Plastics Industry, Industrial Marketing Guides, Bridgewater, New Jersey, 1987, p. 226.

[2] Rauch, p. 1.

[3] We relied on data for 1985 to provide consistency across various sources. Some industry estimates are available through 1986, however.

The industry has managed to prosper despite two energy crises, increasing feedstock prices, severe overcapacity, and chronic price competition. It is currently in a period of high growth because of the high investment in research and development, resulting in the creation of new products and technological improvements in the low-cost basic manufacturing processes.

1. U.S. PRODUCTION OF PLASTICS

a. Current Output of the Industry

As we will discuss later, over half the discarded plastics are from packaging, so we will focus the production discussion on packaging more than on other uses. Over the past decade, materials used in packaging have shifted significantly from relatively heavy metals and glass to relatively light paper and plastics, and this shift is reflected in the output of the plastics industry. In 1985 alone, 12.8 billion pounds of plastics were used in the packaging industry. By the year 2000, the plastic packaging industry will produce 22.58 billion pounds of plastic, a 3.9 percent growth rate through the end of the century.[4] On a dollar basis, plastics were responsible for 20 percent of the value of food packaging materials in 1985; this figure is expected to rise to 40 percent by the year 2000.

The overall industry has a high growth rate: 9.1 percent a year in physical output since 1960 with a rate of plastic production that increased 2 to 3 times as rapidly as the GNP for the same period. The trend toward increased use of plastics is a result of technological improvements in plastics manufacture including

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[4] Chilton's Food Engineering. "Continued Growth Predicted for the Plastics Industry," Chilton's Food Engineering, August 1987, pp. 23, 25.

- More durable and light-weight housings
- Improved appearance and barrier properties of plastic film for food packaging
- Lighter weight, thus enabling soft drinks to be packaged in larger containers

For the consumer, these improvements lead to enhanced quality of food products (more nutritious and bacteria free), greater break resistance of plastic products, the ability of plastic to withstand extremes of temperature, and some reusable plastic products.

While consumers have found clear benefits from the expanded use of plastics, individuals concerned with the fate of plastics in the environment have raised concerns about "appropriate uses." For example, the service life of products, especially those for single use, may be much shorter than their total lifetime. These concerns explain some of the legislative initiatives to control use and disposal of plastics. Clearly the growth of the industry depends on the outcome of debates over use and disposal. We will discuss initiatives to control plastics later in the appendix.

During the next few years, the plastics industry is expected to grow most rapidly in the electronics, packaging, and transportation markets, with slower growth rates for consumer and institutional uses and for building and construction.[6] Factors contributing to this growth include the following:

- Development and use of barrier plastics (plastics providing protection against oxygen, flavor, odor, and solvent permeation)

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[6] Rauch, p. 227, and comments from the Society of the Plastics Industry, May 1988.

- Further development of plastic blends, alloys, and copolymers
- Further development of high-speed, automated processing, and fabricating equipment
- Extended polymers
- Growth of advanced composites for a variety of industrial uses
- Expansion of resin grades for greater applicability within existing markets

Plastics used in packaging have increase from 4.7 billion pounds in 1970 to 12.8 billion pounds in 1985 and may reach 22.6 billion pound by 2000.[6] These plastics used in packaging are dominated (99 percent) by thermoplastics. Thermoplastics soften or melt at high temperatures while thermosets remain rigid. High-density polyethylene (used for bottles and pipe); polypropylene (packaging, appliances); and polyethylene terephthalate (PET, which is used for film and bottles) are thermoplastics that are increasing their share of the packaging markets. The expansion and composition of markets is discussed in the next section.

b. Markets for Plastic Products

In many markets, plastics are viewed as a replacement for traditional materials such as glass, aluminum, and paper. The industry has created many new types of packages as a response to changes in consumer demand, industry demand, demographics, and lifestyle. With the greater emphasis on fast food and convenience, the industry has produced many more disposable plastic containers. As a result of the aging of the U.S population and the declining household size, single-service packages, portion packages, and "microwavable" trays are a growing part of the plastic packaging industry. A new type of dispenser, consisting of a plastic bag inside a box, is now used for wine, juices, and condiments. Plastic containers are replacing metal cans, glass jars, and bottles as a means of packaging soft drinks and juices.

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[6] Society of the Plastics Institute (SPI), Plastics A.D. 2000, 1987, p. 43.

Barrier plastics, which are used to package materials requiring oxygen, carbon dioxide, flavor, odor, and solvent protection, are taking over packaging of mayonnaise, dressings, syrups, and seasonings--a market traditionally dominated by glass and metals. These plastics are also lighter weight and more resistant to breakage than their counterparts. By the year 2000, the industry expects plastic barrier applications to be available for contents requiring high-temperature processing such as baby foods, seafood, and beer.

Another use for plastic is plastic bags and heavy-duty shipping sacks. Plastic shopping bags should expand from 25 percent market penetration in 1985 to 75 percent market penetration by 2000. The market for shipping sacks is predicted to grow at an annual rate of 8 percent over the next decade.[7]

Plastics are also used for structural and semistructural applications in place of many metals. The manufacture of automotive exterior body panels and exterior components from plastics is another avenue for expansion of the plastic market. These new markets, however, are restricted by the cost of development of new types of plastics, so that the trend will generally be toward substitution rather than new applications. In addition, as polymers become more structurally advanced and as cost-performance criteria (cost of production and cost of conversion to the finished product) become more important in the choice of materials, plastics may expand into a variety of building and construction applications previously dominated by metals and wood.

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[7] SPI, p. 44.

The industry has identified several trends that characterize its successes in use of plastics as a substitute for traditional materials:*

- There has been a rapid market penetration. Within 5 years, some applications were converted completely to plastics.
- The large degree of penetration, once achieved, was not reversed.
- Initial plastics substitution may have resulted in use of a higher-quality, more-costly polymer than necessary, because some plastics were over-engineered to ensure adequate performance.
- There has been interpolymer replacement. As manufacturers become comfortable with polymeric materials and experience an improved cost position through their use, the manufacturers will turn to other types of polymers for the same applications.

Table A.C-1 is taken from The Rauch Guide to the U.S. Plastics Industry and provides data on plastics consumption by major markets for 1985. As discussed earlier, packaging is the largest market for plastics, accounting for approximately 1/3 of domestic consumption. The remainder of the uses are for durable goods.

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*SPI, p. 11.

TABLE A.C-1

PLASTIC CONSUMPTION BY MAJOR MARKETS: 1985

(million lbs)

	Total	% of Total
Packaging		
Bottles, jar, vials	2,137	6
Food containers (excluding disposable cups)	2,228	6
Flexible packaging (bags, liners, etc.)	3,081	8
Household and instit. refuse bags and film	2,698	7
All other packages	2,583	7
Total	12,727	33
Building and Construction Total	10,038	26
Consumer and Institutional Products Total	3,975	10
Electrical/Electronic Total	2,659	7
Furniture and Furnishings Total	2,107	5
Transportation Total	1,989	5
Industrial/Machinery Total	364	1
All Other Total	5,122	13
GRAND TOTAL	38,981	100

Source: The Rauch Guide to the U.S. Plastics Industry, 1987, Table 4-24, pp. 226-227, with revisions from the Society of the Plastics Industry, May 1988.

c. Production Inputs

Plastics are obtained through the chemical processing of feedstocks and are converted into polymeric materials such as high-density polyethylene, or polyethylene terephthalate (PET), or other plastic products. Feedstocks for plastics production come from nonrenewable sources: prior to 1940 the primary feedstock used was coal, but it has been replaced by petroleum and natural gas. Current domestic production of plastics requires 5 percent of the oil and less than 1 percent of the gas consumed by the U.S.. Some of the feedstocks for plastics production are wastes or byproducts of the processing of crude oil.

The industry is currently in a good position with regard to petrochemical supply. Within the past decade, nationwide oil consumption has been below predictions; as a result, crude oil prices have remained relatively constant. This trend is expected to continue over the next 10 years, as crude oil production is predicted to increase between 1985 and 1995.

The industry is sensitive to oil prices. Because the feedstocks are derived from petroleum refining, the cost of production depends on oil prices. The industry is also sensitive to plant capacity. Thus, due to limited production capacity, plastic prices can be high at times of low prices for crude oil.

If oil prices were to rise sharply as they did in 1979, or if the dollar fell further, then the growth of the plastics industry would probably slow; the penetration of new markets as well as the replacement of old materials by plastics would be curtailed. The value of scrap plastic would be affected by changes in oil prices and exchange rates. As feedstock for virgin plastic becomes more expensive, scrap plastic will be an economical replacement in some applications.

The major feedstocks for plastics production are listed in Table A.C-2. The plastics industry is the major consumer of several of these stocks such as ethylene, propylene, benzene, and naphthalene.

Plastic resins are produced by processing petrochemical feedstocks and intermediate chemicals in a three-step process. The first step is synthesis in which the basic resin or polymer is produced from various chemical compounds. The second involves formulation, where the resin is mixed and compounded with other materials to form an intermediate. In the final step, which is processing, plastic compounds are processed into useful products or forms by heat and/or pressure.

Over the past two decades, the industry has invested heavily in research and development, which has resulted in new products as well as low-cost basic manufacturing processes and faster, larger processing equipment. Although these processes required a substantial amount of capital investment, they are responsible for a large portion of the industry's growth. For 1985, the rate of investment as a percentage of shipments (4.6 percent) was higher than the rate for all manufacturing.[9]

2. WASTE MANAGEMENT OF PLASTICS

a. Quantity of Disposed Plastics

The increased use of plastics, coupled with the fact that very little recycling infrastructure exists for postconsumer plastics, has contributed to current municipal solid waste disposal concerns. Because of the decreasing availability of landfill sites and the increasing amount of plastic and other municipal solid waste, the local, state, and federal officials

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[9] Rauch, p. 6.

TABLE A.C-2

CONSUMPTION OF MAJOR FEEDSTOCKS FOR PLASTICS IN 1986

Base Stock	Million lbs	% of Total Base Stock Produced
Ethylene	22,400	70
Propylene	7,500	50
Benzene	6,400	67
Methane	2,500	-
Xylene	1,500	27
Toluene	350	7
Naphthalene	250	60
Butadiene	200	6

Source: The Rauch Guide to the Plastics Industry, 1987, p. 54.

are exploring limits on materials entering the solid waste stream. Plastics have already been a target of some laws. Plastics and paper products are increasing more rapidly than any other components of the municipal waste stream.

According to Franklin Associates' 1988 report for the U.S. Environmental Protection Agency (EPA), in 1986 nearly 21 billion pounds of plastics were discarded into the municipal waste stream (so-called gross discards). From that amount, approximately 200 million pounds were recovered, either because of recycling or resource recovery. The balance, 20 billion pounds (10.3 million tons), was landfilled. The majority of the net discards (55 percent or 11 billion pounds) was from packaging with the balance from disposal of durable goods.[10] Figure A.C-1 illustrates the disposition of plastics, combining our earlier data on consumption of plastics with its applications and disposal.

The net discards of plastics have increased substantially since 1960 when 0.8 billion pounds of plastics were discarded, representing 0.5 percent of the total weight. By 1986, this figure had risen to over 20 billion pounds and 7.3 percent of the waste stream. By 2000, it is projected that 31.2 billion pounds of plastics will be discarded into the waste stream (9.2 percent of the total). Table A.C-3 presents net discards of plastic and its share of the waste stream from 1960 to 2000.

The environmental and health consequences of landfilling plastics are uncertain. Plastics have drawn attention for their persistence in litter, but we are unaware of evidence that specifically links plastics in landfills to potentially harmful air or water emissions. Plastics are stable in the landfill environment. A study of cadmium leaching from pigmented plastics that had been disposed of in a landfill found that landfilling is an acceptable disposal option that would not result in significant release of cadmium to the environment.[11]

One other important parameter of plastics disposal is the volume of waste. Citing EPA data, an article in Materials Engineering estimated that the physical volume of plastic waste was 78 million cubic yards in 1984. With a weight of 10 million tons in 1984, the density of the material would have been about

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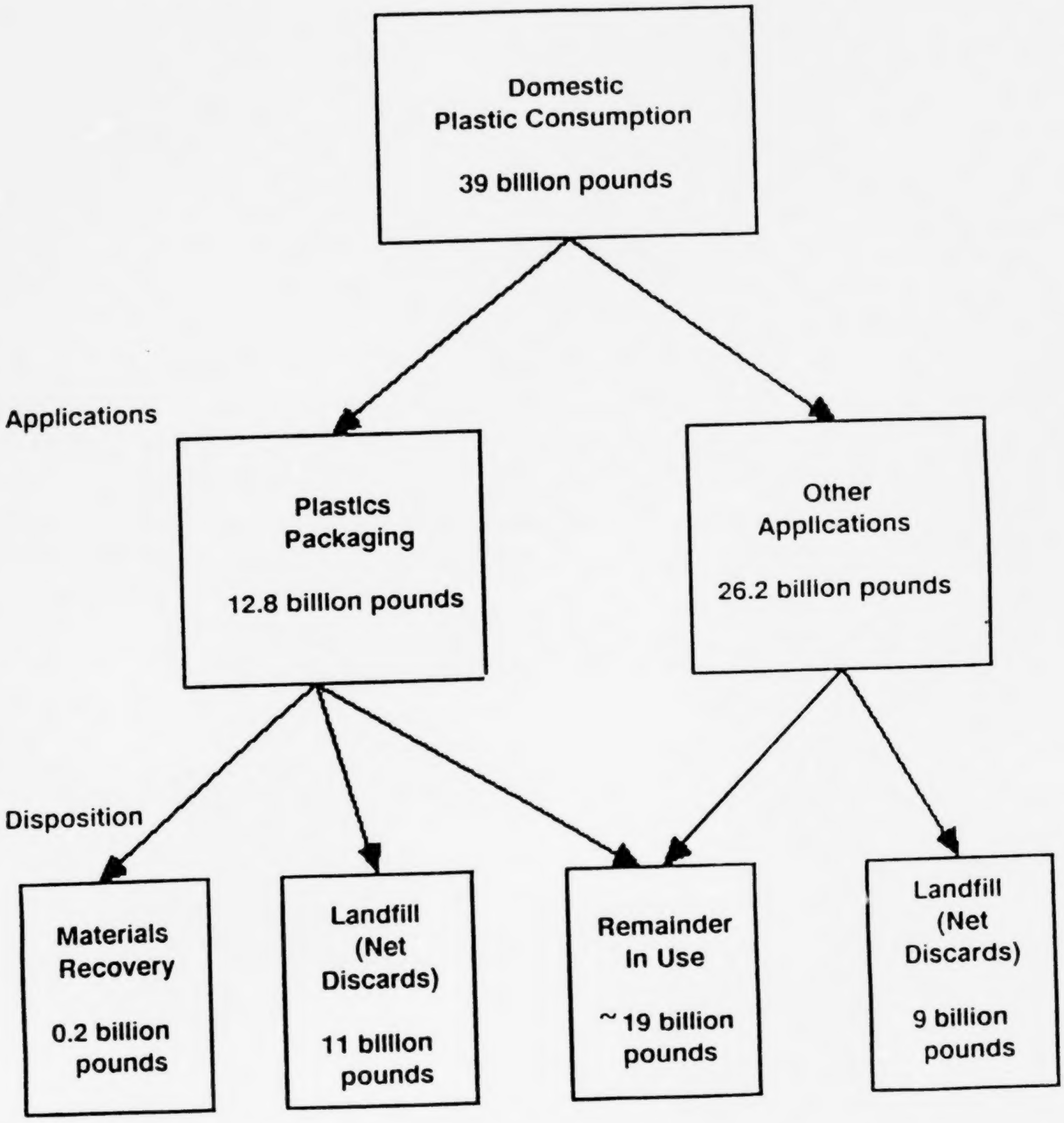
[10] Franklin Associates, Ltd. Characterization of Municipal Solid Waste in the United States, 1960 to 2000, 1988 Update, prepared for the U.S. Environmental Protection Agency, Office of Solid Waste, March 30, 1988.

[11] Environmental Science and Technology. "Leaching of Cadmium from Pigmented Plastics in a Landfill Site" Environmental Science and Technology, Vol. 16, No. 9, 1982, pp. 560-566.

FIGURE A.C-1

ESTIMATED DISPOSITION OF PLASTICS - 1985



Sources: Rauch Guide to the Plastics Industry, 1987; Franklin Report, 1988; Temple, Barker & Sloane, Inc. (TBS) calculations.

TABLE A.C-3

PLASTICS DISPOSED TO THE MUNICIPAL WASTE STREAM

(billions of pounds)

	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986	1990	1995	2000
Plastics Disposed	0.8	2.8	6.0	8.8	15.2	15.6	16.8	18.2	19.2	19.4	20.6	23.6	27.4	31.2
Total Municipal Waste Disposed	163.4	192.2	225	232.4	258.4	263.2	258.2	269	276.6	274.6	281.6	298	317.8	337.6
Percentage of Plastics	0.5%	1.5%	2.7%	3.8%	5.9%	5.9%	6.5%	6.8%	6.9%	7.1%	7.3%	7.9%	8.6%	9.2%

Source: Franklin Associates, Ltd. Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988), p. 6-7, 1988.

250 pounds per cubic yard.[12] Landfill densities for mixed municipal solid waste are several times higher, ranging from 800 pounds per cubic yard for small landfills to as much as 1,200 pounds per cubic yard at large landfills. These figures indicate that a given weight of plastic waste has a larger volume than the same weight of combined municipal solid waste.

b. Incineration of Plastics

Plastics can release up to four times the amount of energy of the average mix of municipal solid waste (as much as 15,000 to 20,000 btu/lb), twice the heat content of Wyoming coal, and nearly as much as residual fuel oil. Thus they contribute substantially to the heat value of municipal solid waste and to the energy recovered.

EPA, local officials, and environmentalists are all concerned with the consequences of burning plastics. At issue are the combustion properties of plastics, their value as a high-BTU-content component of the waste stream, their emissions, and the residual in ash. Both industry and government are studying these issues. According to representatives of the plastics industry, a test at an incinerator in New York produced no evidence that the amount of PVC in the waste affected levels of dioxins or furans. EPA is reviewing this study.[13]

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[12] Materials Engineering. "Waste: Problem and Opportunity for the Plastics Industry," Materials Engineering, February 1988, p. 26.

[13] Midwest Research Institute. Results of the Combustion and Emissions Research Project at the Vicon Incinerator Facility in Pittsfield, Massachusetts, Final Report (Volume I), prepared for New York State Energy Research and Development Authority, June 1987.

c. Recycling

Plastics recycling has become an extremely visible issue in the past several years. The plastics industry formed the Plastics Recycling Foundation in late 1984 in response to concerns over the ultimate fate of plastics in the environment. Plastics recycling is not new, as we will discuss in the section on current recycling; the industry has recycled resins at the manufacturing and fabrication stage ever since the early 1970's. Recycling postconsumer products (e.g., soft drink bottles and other beverage containers), however, is a newer idea.

The industry recently announced the formation of the National Association for Plastic Container Recovery (NAPCOR), which is launching a program to increase PET recycling. Their goal is to increase PET recycling by 20 percent (30 million pounds) in 1988 with state-by-state programs in Florida, Kentucky, Minnesota, North Carolina, Rhode Island, Texas, and Washington. A substantial increase in collected PET could also come from California as its new beverage container recycling program gets underway.

In this section we will address current recycling, potential recycling levels, and barriers to recycling.

(1) Current Recycling

Recycling of plastics occurs in two different ways: at the manufacturing and fabrication stage of production and after the plastic is sold to the consumer.

The more established of these practices is in-plant recycling of resins by the manufacturers. The practice began on a large scale in the early 1970's when soaring energy prices drove up the price of feedstocks and made scrap material recovery an economic necessity. The manufacturers have not, thus far, collected industry-wide data on the extent of this recycling, but the Society of the Plastics Industry is attempting tc compile data. One source we reviewed suggested that approximately 75 percent of the plastic waste generated during fabrication is reused. In addition, off-spec resin is recycled by many plastic producers and reprocessed into saleable products. Unlike plastic packaging waste, this waste is uncontaminated and easily collected, making recycling a much more attractive proposition.[14]

Current recycling of postconsumer plastics is more easily quantified. Franklin Associates' study of the solid waste stream indicates that about 1 percent of the gross discards of plastics is recovered. This amounts to approximately 200 million pounds of recycled plastic.

The recycled postconsumer plastics are virtually all from bottles made from PET and high-density polyethylene (HDPE). PET containers are used most widely for soft drinks and HDPE is used to make containers for products like detergent and milk.

Collection of these materials presents a substantial barrier to further recycling, as we will discuss below. For PET, this barrier has been partially overcome by mandatory container deposit programs in nine states. In these states, PET is collected along with other container types by bottlers, distributors, or third parties. These states provide most of the PET currently recycled.

PET beverage bottles are recycled to create a variety of products. In 1985, 20 percent of all PET soft drink bottles were recycled into such products as fiberfill, strapping, thermoformed sheet, coextrusions, high-temperature PET foam, woven geotextiles, extrusion-coated plywood, and roofing membrane, as well as being compounded, blended, and alloyed into various engineering polymers. Table A.C-4 shows the distribution of materials produced from recycled PET. Most of the PET recycled in 1987 was for fiber, but projections for 1992 suggest a fourfold increase in the amount recycled and expansion into several new areas such as injection molding and extrusion.

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[14] Modern Plastics. "Industry Begins to Face Up to the Crisis of Recycling," Modern Plastics, March 1987, p. 45.

HDPE is also being recycled. Table A.C-4 shows that the 53 million pounds of HDPE reclaimed in 1987 were made into pipe, carstops, marine products, stadium seating, livestock feeding equipment, and base cups for soft drink bottles.

(2) Recycling Potential

We compiled information on the potential for increasing the recycling of these container types and the effect it would have on the solid waste stream. Figure A.C-2 indicates how PET and HDPE containers fit into the plastics market. Out of the 39 billion pounds of plastics consumed in 1985, 12.8 billion pounds were for packaging. The industry reported that in 1986 it used 2.9 billion pounds of packaging for bottles.[18] Of that total, 2.5 billion pounds, or 86 percent were made from PET or HDPE, making that volume "recyclable" given current technologies. The remaining polymers have not been recycled on a large scale thus far.

If all 2.5 billion pounds of PET and HDPE bottles were recycled (a 12-fold increase over 1987's 200 million pounds), the

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[18] Plastics Recycling Foundation Plastics Recycling: A Strategic Vision, March 1988. We were unable to obtain these data for 1985 to remain consistent with the other figures in the appendix; these estimates are sufficiently accurate to support our projections, however.

TABLE A.C-4

RECYCLED END USES FOR PET AND HDPE

(millions of pounds)

PET	1987	1992
Fiber	90	180
Injection Molding	25	160
Extrusion	25	130
Non-Food Grade Containers	--	30
Structural Foam Molding	--	30
Paints, Polyols, Other Chemical Uses	10	20
Stampable Sheet	--	30
Other (yet unidentified)	--	20
Total	150	600

HDPE	1987	1992
Bottles (non-food)		115
Drums		25
Pails	20	65
Toys		15
Pipe	30	80
Sheet		25
Crates, Cases, Pallets		105
All Other	4	130
Total	53[1]	560

Source: Plastics Recycling Foundation.

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[1] Totals may vary because of rounding.

FIGURE A.C-2

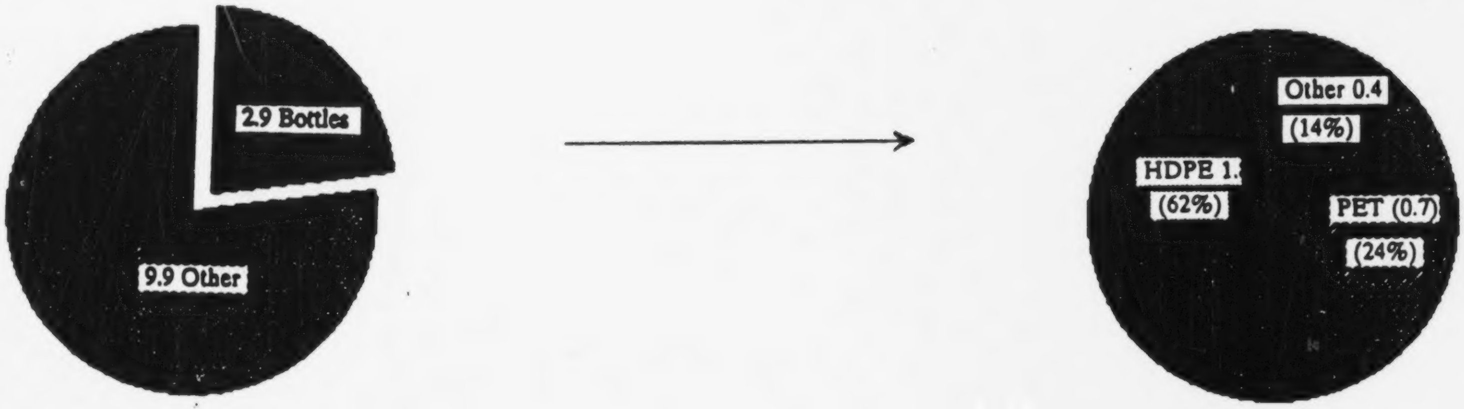
ORIGIN OF CURRENTLY RECYCLED POLYMERS

(PET and HDPE)

1985 Plastics Consumption for Packaging (12.8)

(billions of pounds)

Polymers Used in Plastic Bottles (2.9)



Source: Plastics Recycling: A Strategic Vision, Plastics Recycling Foundation, March 1988.

recycling rate for the industry could reach 13 percent (2.5 billion pounds out of 20 billion net discards). The Plastics Recycling Foundation estimates that the total market for recycled PET and HDPE is about 10 billion pounds, so market saturation should not be a problem. The major barrier to expanding this existing recycling is collection of materials as discussed in the next section.

Of the roughly 560 to 570 million pounds of PVC currently being used in packaging applications, very little is being recycled.[16] Although a 3.4-billion-pound market for recycled PVC does exist for production of plastic pipe and drainage pipe, there is no infrastructure yet in place to facilitate the recycling of PVC. There is also no mechanism for separation and collection of the PVC, although scrap from the bottle producers is being reused.

(3) Barriers to Recycling

The current barriers to plastics recycling include technical barriers (no collection infrastructure, no technology to separate some materials); market and economic barriers (lack of markets); and information barriers (lack of consumer acceptance and knowledge).

Technical Barriers. The first technical barrier that primarily affects the expansion of existing recycling programs is the lack of an established sorting and collection system for plastics. While states with mandatory container deposits already have some system in place, plastics recycling is beginning more slowly elsewhere. Pilot recycling projects including plastic have begun in Massachusetts, New Jersey, and Rhode Island, encouraged at least in part by mandatory recycling bills. Compared to the recycling infrastructure for paper, glass, and aluminum, however, plastics is behind.

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[16] Gottesman, Roy, Staff Director of the Vinyl Division, Society of the Plastics Industry. Personal communication, June 6, 1988.

Another barrier to recycling is the difficulty in separating plastic, especially given the relatively small fraction for which markets exist (PET and HDPE). With the exception of mixed plastic recycling (discussed below), recycling depends on separating plastics by polymer type. The industry has announced a voluntary plastic container coding system that would at least identify the plastic used in the container, but sorting the materials will still require time and effort.

Market/Economic Barriers. PET and HDPE are the only polymers with established scrap markets. For other plastics, entrepreneurs will not incur the cost of collecting used plastics, only to find that the material must be landfilled. Pilot projects are, however, creating small, localized markets for other polymers. Even in situations where markets do exist, plastics are expensive to transport because of their low density.

Information Barriers. Industry research has shown that the average citizen is unaware that plastics can be recycled. In California, the industry is pushing for a high recycling rate to comply with state law. As the first step to increasing collection, the industry is promoting the fact that plastic can be recycled. Consumers are skeptical of goods made from recyclable material, although this is not unique to plastics.

Consumers are also not aware of the value of plastic containers as scrap. Typical scrap prices for PET and HDPE are about 6 cents per pound, or about 1 cent per 2-liter container. An aluminum can is currently worth about 3 cents each (about 70 cents per pound). Newspaper, another commonly recycled product, is worth much less than aluminum or plastic, about 1.5 cents per encouraged at least in part by mandatory recycling bills. Compared to the recycling infrastructure for paper, glass, and aluminum, however, plastics is behind.

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(4) Enhanced Ability to Degrade

One other aspect of plastics waste management is the issue of being able to degrade the plastic. While the marketing focus of the industry has always been on stability and durability, now some individuals are calling for more degradable plastic packaging; several states have passed laws requiring that loops made to connect 6- or 8-packs must be degradable. Degradable plastics are viewed primarily as a solution to concerns about litter and marine pollution. Marine pollution is the focus of The Plastic Pollution Research and Control Act (PL-100-220). EPA and other agencies are studying the effect of plastics on the marine environment and will address these separately. Regulations banning ocean discharge of plastic waste will be in place by the end of 1988.

Plastics already are degradable to a limited extent, but the industry is also enhancing that ability. The industry has already developed photodegradable plastics: those that break down under exposure to ultraviolet wavelengths in sunlight. Biodegradable plastics are more experimental, and current approaches depend on a starch-based polymer that is eventually degraded by enzymes in the environment. In some cases, degradable plastics may help solve specific litter or waste problems, and research is continuing.

Ability to degrade is not an ultimate solution to plastics disposal, because it is not a feasible property for plastics in all uses. Also, degradation products may ultimately cause more damage than the original waste, and degradable plastics may adversely affect the ability to recycle mixed plastics.

(5) Source Reduction

Current interest in source reduction focuses on influencing manufacturers to produce goods with either reduced waste volume or lower toxicity. A program in Rhode Island is pursuing public and private cooperation in designing products for increased ability to recycle and reduced waste volume. Development of these programs depends heavily on consumer demand for these lower-volume/lower-toxicity products.

d. Proposals and Legislation

Government officials at the Federal, State, and local levels are considering legislation that would limit the amount of plastics produced or disposed of. This legislation has various purposes ranging from reducing litter to keeping plastics out of incinerators or landfills. Congress is considering legislation that could, in the extreme, ban plastics for certain uses. Other components of proposed legislation include waste reduction, increased recycling, and increasing use of degradable plastics.

Currently, 14 states mandate return of or deposits on beverage containers (9 states with mandatory deposits, plus California, Connecticut, Maryland, New Jersey, and Rhode Island). The deposit bills were aimed largely at litter problems, but the more recent recycling legislation focuses on landfill capacity issues and, accordingly, affects a larger fraction of the solid waste stream than the deposit bills do.

New Jersey passed a stringent law in 1987 requiring that the recycling rate of plastic beverage containers be equal to the lesser of the recycling rates of glass or aluminum. Curbside separation and collection of at least three recyclable materials must be ongoing by July 1988, and each county must meet a recycling rate of 25 percent for all materials by the second full year of operation.

New York is reexamining its methods of municipal solid waste management--waste reduction, recycling and reuse, waste to energy, and landfilling--with the goal of reducing waste going to landfills by up to 50 percent over the next 10 years.

California is approaching the plastics waste disposal problem differently: distributors must pay the state 1 cent per beverage container sold. The pennies are returned to consumers when they return the containers. Container manufacturers are then assessed a processing fee on each container sold if the scrap value does not equal the state-calculated cost of redeeming and processing the empty containers. By December 1989, those container types that are not at a 65 percent recycling rate will be assessed a refund value of 2 cents per container, and that figure will increase to 3 cents per bottle in December 1992 if the 65 percent rate is still not achieved.

On the national level, the Resource Conservation and Recovery Act is due for reauthorization in 1988; Congress may consider revisions to the Act that specifically deal with the problem of the disposal of plastics into municipal landfills. In addition, Congress has already requested reports on reducing plastics pollution and on the effects of plastics on the marine environment.

e. Research and Development

Although recycling of plastics is not as widespread as that of aluminum or paper, some companies have invested capital in research and development and are undertaking recycling projects. With improvements in these technologies and the addition of new firms into the recycling business, the amount of plastics recycling is likely to increase substantially over the next several years.

Industry projects geared toward the recycling of plastics are addressing intake of materials, cleaning, sorting, and development of new products.

(1) Collection

Many firms are developing methods for collecting, cleaning, and reclaiming plastic products such as blow-molded HDPE oil, detergent, and milk containers. Plans are also underway to build balers and other equipment designed to match demand arising from mandatory curbside recycling laws such as those in New Jersey. In addition, industrial PVC scrap and resin moldings are being used to mold parts, while other ways of tapping postconsumer sources of PVC are being explored.

(2) Separation Technology

Another step in the process of recycling plastics involves separation of the container components. One technique currently available on a low-cost, nonexclusive basis is one that separates the container components by flotation and electrostatic systems. Several firms have plans to expand PET reclamation capacity using component separation technology. PET component separation systems yield HDPE clean enough for reuse as black-base cups. HDPE can also be converted into fuel pellets for energy production.

(3) Commingled Recycling

Commingled recycling, the conversion of scrap plastics into a wood replica material using PET, PVC, polystyrene, and polyolefins, has been used in several recycling plants. In some applications, it provides a cost-effective replacement for wood, which can be sawed, cut, or nailed to make fencing, planks, boardwalks, docks, outdoor furniture, benches, and road markers. Given the high costs to sort plastics and the lack of strong markets for recycled plastics other than PET and HDPE, this could be an increasingly attractive recycling option. Some firms are geared toward recovering the undifferentiated scrap resulting from plastic packaging. This heterogenous scrap is reprocessed into a homogenous mass at a high temperature and is extruded as a paste for conversion into flooring, fencing, barriers, crates, and flower pots.

(4) Reprocessing

Once the plastic scrap has been collected and separated into component parts, the reprocessed PET can be used for a variety of applications. Among these are acrylic scrap, which can be remonomerized as binder in polymer concrete, and HDPE milk jugs, which can be reprocessed into polymer lumber for agricultural and construction markets. Reprocessed PET can also be used for blending compounds and film. New markets are being developed for these products of plastic recycling.

3. CONCLUSION

As a result of the publicity surrounding landfill capacity, litter, and incinerator emissions problems, industry and government are under pressure to respond to national solid concerns; plastic waste is a part of these issues.

Especially in the past year, the plastics industry has reacted to concerns over the high volume of plastics disposed of and the lack of markets and information for recycling. The major obstacles facing plastics recycling are

- The difficulty and cost of postconsumer separation
- The lack of markets available for recycled plastics other than PET and HDPE
- The absence of large-scale collection systems
- The low density of scrap plastic, making it difficult to handle and expensive to ship

In addition to research and development to overcome these obstacles, further study of the environmental and human health effects of alternative waste management options (especially landfilling and incineration) is necessary.

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TABLE OF CONTENTS

APPENDIX A

D. FOOD AND YARD WASTE

Page

1. QUANTITY AND TRENDS A.D-1
    a. Food Waste A.D-1
    b. Yard Waste A.D-2

2. VARIATIONS: SEASONAL AND REGIONAL A.D-2
    a. Food Waste A.D-2
    b. Yard Waste A.D-3

3. MANAGEMENT PRACTICES A.D-6
    a. Composting - Food Waste A.D-6
    b. Solid Waste Composting A.D-10
    c. Composting Yard Waste A.D-11
    d. Incineration/Energy Recovery - Food Waste A.D-17
    e. Incineration/Energy Recovery - Yard Waste A.D-17
    f. Landfilling - Food Waste A.D-18
    g. Landfilling - Yard Waste A.D-18
    h. Management Trends A.D-18

4. PROBLEMS A.D-19
    a. Food Waste A.D-19
    b. Yard Waste A.D-20

REFERENCES A.D-22

APPENDIX A
MAJOR WASTE STREAM COMPONENTS

D. FOOD WASTE AND YARD WASTE

This appendix provides a summary of characteristics, current management practices, and disposal problems for food and yard wastes in the United States. In the municipal solid waste stream, food and yard waste make up an unusual component in that they are highly organic. Food waste is characterized as vegetative and animal byproducts from household food scraps, restaurants, food processing facilities, and grocery stores. Yard waste includes vegetative material (i.e., leaves, grass, brush, tree trimmings) from lawn, garden, and tree maintenance activities.

1. QUANTITY AND TRENDS

a. Food Waste

In 1960 food waste composed 14.9 percent of the municipal solid waste stream, or 12.2 million tons. By 1970 the percentage of food waste had dropped to 11.4 percent of the waste stream, but the quantity actually increased to 12.8 million tons. In 1986 the percentage of food waste in the municipal waste stream dropped even further to 8.9 percent, but the quantity remained relatively the same at 12.5 million tons.[1] By the year 2000, the percentage of food waste is projected to decline to 7.3 percent of all waste disposed, or 12.3 million tons. This drop in the percent of the waste stream is due to a rapid growth in other discarded wastes, such as paper and plastics, which account for an increasing portion of discards thereby diminishing the impact of food waste. This decrease is also due to increased use of garbage disposals and prepackaged foods in the United States.

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[1] Franklin Associates, Ltd. Characterization of Municipal Solid Waste in the United States, 1960 to 2000, Update 1988, prepared for the U.S. Environmental Protection Agency, Office of Solid Waste, March 30, 1988.

b. Yard Waste

Yard waste is difficult to quantify on a national basis because seasonal and regional variations can be drastic. These variations are described in the following section. Nationally, yard waste composed 20.1 percent of all waste disposed in 1986 for a total of 28.3 million tons.[2] Yard waste is the second largest component of the waste stream behind only paper and paperboard. The volume of yard waste has been steadily increasing from 20 million tons in 1960, to 23.2 million tons in 1970, to 28.3 million tons in 1986. An increase of 3.7 million tons (to 32 million tons per year) is anticipated for the year 2000. The percentage of yard waste in the waste stream is expected to decline because of the rapidly increasing generation of other wastes. The percentage of yard waste in the total municipal waste stream has decreased from 24.5 percent in 1960, to 20.6 percent in 1970, to 20.1 percent in 1986. Yard waste is expected to compose only 19 percent of the waste stream by the year 2000. Unlike other wastes, yard waste is generated primarily by the residential sector.

2. VARIATIONS: SEASONAL AND REGIONAL

a. Food Waste

There is little fluctuation in the generation of food waste throughout the year. Typically, the percentage of food waste in the waste stream increases in winter months because of a corresponding dramatic decrease in yard waste generation. On a weight basis, food waste disposal is fairly consistent throughout the year.

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[2] Franklin.

There are regional variations in the amount of food waste disposed of although discrepancies may arise due to regional sampling methods and differences in definitions of waste types. According to a 1981 study, food waste composed 2.8 percent of waste disposal in San Diego, California, in 1981 and 21.9 percent of waste disposal in Butte, Montana.[3] These differences may be attributed to the type of waste accounted for (residential, commercial, industrial); the types of businesses located in a community; the classification of wastes (some food wastes may be called yard wastes and vice versa, e.g., spoiled garden vegetables); and the time of year wastes were surveyed. In general, food waste composes a greater percentage of waste disposal in urban areas than in rural areas because restaurants, grocery stores, and large food processors are more frequently found in urban areas.

b. Yard Waste

Yard waste quantities are difficult to accurately assess because variations may be evident between neighboring communities, regions, and seasons. Localized weather conditions may produce large quantities of yard waste in a short period of time (downed trees from storms). Different regions of the country experience climatic differences that result in variations in growth periods, vegetation types, and yard waste composition. In general, yard waste disposal peaks during the summer and slows drastically nationwide in the winter. Table A.D-1 indicates generalized seasonal variations for Portland, Oregon. When surveyed in the fall, the waste stream contained 14.5 percent yard waste. A winter sample resulted in only 2.8 percent yard waste. In general, the composition of yard waste nationally varies by season as follows:

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[3] City of St. Paul. Solid Waste Energy Recovery Project, Phase II, Department of Public Works, City of St. Paul, Minnesota, December 1981.

- Spring: Tree trimmings and prunings are the largest component. Grass clippings are also apparent in warmer climates.

- Summer: Grass clippings are the largest component. Some garden wastes and tree trimmings are present. Composition is fairly uniform nationwide.

- Fall: Leaves predominate. Grass clippings, garden waste, and tree trimmings are found in lesser quantities. Leaves are subject to regional differences and are often limited to a 2- to 4-week peak.

- Winter: Prunings predominate. Northern States generate little or no yard waste.

TABLE A.D-1

ESTIMATED AVERAGE SEASONAL YARD WASTE COMPOSITION
FOR PORTLAND, OREGON
(Weight % of Total Waste Stream)

Summer	Fall	Winter	Spring
10.66	14.52	2.76	13.64

Source: Waste Stream Characterization Study, Portland Metropolitan Service District, Oregon, SCS Engineers, RCC, Coffey Laboratories, Inc., November 1987.

Table A.D-2 shows differences throughout the United States in the proportion of yard waste in the total waste stream.

TABLE A.D-2

ESTIMATED YARD WASTE IN WASTE STREAM, BY AREA
(percent by weight)

Area	Weight % Yard Waste Annual Average
Rochester	9.1[1]
San Diego	20.7[1]
Missoula	29.6[1]
Butte	14.3[1]
Billings	12.2[1]
Ben Lomond	2.3[2]
Buena Vista	7.7[2]
Marquette	10.0[1]
Springfield	15.6[1]
New Jersey	22.6[3]
Kentucky	4.4[3]
Ohio	8.1[3]
Pennsylvania	15.3[3]

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[1] City of St. Paul. Solid Waste Energy Recovery Project, Phase II, Department of Public Works, City of St. Paul, Minnesota, December 1981.

[2] Savage, G. M., L. F. Diaz, and C. G. Golucke. "Solid Waste Characterization", Cal Recovery Systems Richmond, Biocycle, November/December 1985.

[3] Wisconsin DNR Report, August 1984.

Other local factors may also affect the rate of yard waste generation. These factors include socioeconomic conditions and population density. Studies have shown that higher income areas generate more yard waste than low income areas.[4] High-population density dwellings (such as apartments) and rural areas do not generate as much yard waste as areas with concentrated single-family residential housing.

3. MANAGEMENT PRACTICES

Food and yard wastes are generated, handled, and sometimes disposed of in different ways. Discussion of management practices, therefore, will separate food waste and yard waste.

a. Composting - Food Waste

In rural areas of the United States, backyard composting of food wastes is fairly commonplace. In some communities, backyard composting of kitchen scraps is supported and publicized (e.g., Portland, Oregon; Seattle, Washington; the states of Wisconsin and California; and others). However, in the other areas, backyard composting of food waste is discouraged because food byproducts can attract animals and insect pests.

Food waste is not known to be composted at large-scale, outdoor composting facilities that are dedicated strictly to food waste or food waste combined with yard waste. Composting of food waste in this manner is inappropriate because of the potential to attract animal and insect pests. In addition, odors are frequently generated by food wastes, and food waste is difficult to separate from other wastes for collection and transport. Composting of food waste is conducted only in conjunction with mixed solid waste composting facilities where waste is deposited, processed, and often composted indoors. This process reduces problems associated with pests and odors and avoids the need to collect separated food waste for transport to a specialized compost facility.

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[4] National Solid Wastes Management Association. Basic Data: Solid Waste Amounts, Composition, and Management Systems, Technical Bulletin #85-6, National Solid Wastes Management Association, 1985.

In general, two large-scale composting methods for mixed solid waste are practiced. Unlike backyard composting or low-tech yard waste composting, both methods of solid waste composting require construction of a physical plant and the dedicated use of certain heavy equipment. A fairly low-technology approach has been implemented in several low-population, low-waste-volume rural areas. This approach includes construction of a basic building to house equipment, a tipping floor, and active compost piles. Equipment often includes front-end loaders to move garbage and construct windrows, a scale, a shredder or grinder to reduce size of incoming waste, conveyors for materials movement, a mixer to add moisture or sludge, aeration pipes to force air into windrows, a magnet for ferrous removal, and a screen for removal of materials from finished compost. A high-tech system often includes a grapple crane, a rotational drum, in-vessel composting equipment, a windrow turner, and a shredder for finishing compost. Operations are typically provided under turnkey or full-service arrangements from a number of manufacturers. High-tech solid waste composting is most appropriate for communities with a throughput of 75 tons a day or more, because it is normally not economically feasible for manufacturers to offer turnkey or full-service contracts for small projects.

Solid waste composting facilities are much more common in Europe and Asia than in the United States. Approximately 300 facilities are located in Europe; some have been successfully operating for over 30 years. For example, in the Netherlands over 17 percent of all domestic refuse is composted. Between 3 and 10 percent is composted in Switzerland, and similar volumes are composted in other European and Asian countries.

The process of composting solid waste involves reducing the size of incoming material (by grinding or shredding) and removing recyclables to produce a more homogeneous material. Moisture is added because composting can be conducted only if proper moisture levels are maintained. Often, sewage sludge is added as a moisture source that also adds essential nutrients (such as nitrogen). The addition of sludge or similar substances (such as manure) is called "co-composting" because two wastes are composted together.

A finished solid waste compost is a coarse, humus-like soil conditioner. Chemically, solid waste compost is not a good fertilizer because nitrogen, phosphorous, and potassium levels are low. Co-composting with sewage sludge increases nitrogen levels but also adds trace metals that may cause concerns if the compost is used for consumable crops. Compost is a poor thermal conductor, so addition of compost to soil does not accelerate soil warming in the spring. Porosity and soil pH buffering are generally improved with the addition of compost.

Markets for finished compost include nurseries, sod growers, vineyards, groundskeepers, landscaper contractors, parks departments, road contractors, farmers, and landfill operators. Solid waste compost has supplemented or replaced manure, peat moss, mulch, or topsoil in various applications. When markets cannot purchase all the compost produced, governmental users often fill the gap. For instance, compost can be a good landfill cover.

The markets available for the compost and the revenue it will bring depend on the quality of the product and the local or regional demand. The quality of finished compost is measured by its particle size, color, moisture content, carbon-nitrogen ratio, and metals content. Compost will be in higher demand in areas characterized by clayey or sandy soils, in erosion-prone areas, or in areas with high concentrations of nursery or landscape businesses. Markets for the material are typically public agencies, land reclamation projects, and lawn and garden industries.

Capital costs of buildings and engineering for solid waste compost equipment range from $400,000 (1987 dollars) for a low-throughput, low-technology system (such as at Fillmore County, Minnesota) to $73 million (1983 dollars) for a higher-throughput, high-technology system, (such as at Wilmington, Delaware). Site costs depend on the availability of property, the size and location of the facility, and the level of services provided. Some municipalities or counties own property that could be suitable for a compost facility. Other municipalities may have to purchase property. Site size needed will range from 5 to 20 acres, depending on the throughput and potential buffering requirements from adjacent properties. Costs for purchasing a site depend on local or regional differences in land costs, distance from service area, availability, and acreage needed. Site development costs depend on type of soils, drainage, and buffer potential.

Annual operating and maintenance expenses for a solid waste composting facility include costs for management and labor, equipment maintenance, equipment replacement, utility and fuel, building and grounds maintenance, suppliers, insurance, residuals disposal, taxes, publicity, and debt service. On a per-ton basis, these costs range from $9 per ton at the plant in Providence, Rhode Island, to $50 per ton at several facilities in Sweden.

Some examples of operating mixed solid waste composting facilities are outlined below.

b. Solid Waste Composting

- Fillmore County, Minnesota: Using a low-technology approach, this facility has been operating since late 1987. Recyclables are sorted by hand, and the remaining waste is shredded and composted in static, aerated windrows. Finished compost will be sold to area farmers. The facility handles about 20 tons of solid waste a day. About 30 percent by weight is landfilled. A source-separation recycling program has not been implemented as planned, which has had an adverse impact on the quality of the compost.

- Wilmington, Delaware: This facility has operated successfully since 1983. It handles 1,000 tons of solid waste and 350 tons of sewage sludge daily. Waste is shredded, air classified, separated magnetically, and sent through a trommel screen. The light fraction (about half of all waste) is refuse-derived fuel (RDF) and is sent to a boiler plant. The heavy fraction, following removal of metals and glass, is mixed with sludge and composted. Some finished compost is sold for lawn-seeding mulch and bedding in poultry broiler houses. However, about 50 tons of residue is landfilled daily due to lack of markets. Some minor operational and equipment problems were experienced during startup but have been resolved; and the facility is operating smoothly.

- Gent, Belgium: This facility is integrated with an incinerator for burning most of the waste produced in this city of 250,000. The compost plant has operated since 1964 and handles 280 tons of refuse per day. Waste is conveyed to a rotating drum for size reduction. Compost is placed in static piles until it is ready for sale to vineyards. Finished compost is high in lead content, which may be caused by car batteries or car emissions. Because of its age, the facility will be either repaired or replaced. Some equipment breakdowns and marketing problems have been experienced.

The United States has about a dozen facilities for solid waste composting. Two are in Delaware, and one is in each of the following states: Florida, Kansas, Kentucky, Maryland, Minnesota, New Hampshire, New Jersey, Pennsylvania, Ohio, Oregon, Rhode Island, and Wisconsin. Many projects are in the planning stages, including two 400-ton-per-day municipal solid waste (MSW) plants in Florida; two RDF residuals composting plants in Minnesota; at least ten MSW plants in Minnesota; one RDF/compost plant in New Jersey; and potential facilities in Florida, Massachusetts, New York, and North Carolina. Hundreds of similar facilities exist in Europe and Asia.

Not all solid waste composting facilities have been successful. Before 1960, a lack of grinders and other materials-handling equipment deterred the development of solid waste compost facilities. Use of commercially available equipment resulted in excessive wear and tear, which increased operational expenses.[8] Early facilities met failure because of inexperienced operators, lack of financial backing, lack of markets, and technological deficiencies.

c Composting Yard Waste

Backyard comosting of yard waste, as well as the use of grass clippings and chipped brush as mulch, is currently practiced by some homeowners. The City of Seattle has a goal that about 18.5 percent of all yard waste collected would be reduced through backyard composting and mulching.[6] To reach this goal, Seattle plans to initiate a door-to-door informational and instructional program, provide funds to assist homeowners in purchasing compost bins, and provide general information. Other communities currently provide general information to homeowners interested in backyard composting.

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[8] Biocycle. "25 Years Ago in Solid Waste Composting," Biocycle, October 1987.

Large-scale composting of yard waste is becoming more common throughout the country as communities realize the advantages of processing yard waste efficiently. Composting is often more economical than land disposal.

Yard waste compost facilities can be implemented using low-tech, medium-tech, or high-tech methods. In general, higher technologies require more capital, more annual financial commitment, and more control over the compost process but produce a finished, higher-quality compost in less time using less space than lower technologies.

- Low-Tech: Leaves, grass clippings, and brush are generally placed in piles in residential backyards or neighborhood locations for eventual composting. Piles are typically turned or watered very infrequently, if at all. A general rule is that 1 acre is needed to compost 5,000 to 6,000 cubic yards of incoming yard waste. It may take 24 to 36 months for a finished compost to be available. The finished compost may be of low quality since no effort is normally made to separate incoming materials or screen materials such as wood, metal, and plastics after the process is complete. Markets are primarily limited to home use and fill material. Low-tech processing is widely used in smaller communities, individual backyards, and rural areas where volumes of yard waste are low.

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[6] City of Seattle. Yard Debris Composting Program Design, City of Seattle, Washington, Seattle Solid Waste Utility, March 1988.

- Medium-Tech: A medium-tech composting process involves forming windrows (12 to 14 feet wide by 6 feet high), periodic turning and watering of windrows, and increased control of incoming and final product materials. Increased control (when compared to a low-tech system) raises costs somewhat, increases space requirements (1 acre for every 3000 to 3500 cubic yards of incoming material), decreases time for processing (18 to 24 months are required), and improves the quality of endproducts. Medium-tech processing is frequently implemented in areas where ample space is available or quantities of yard waste are low.

- High-Tech: High-tech processing of yard waste involves specialized equipment, full-time operators, monitoring of conditions, and aggressive marketing. High-tech is used where space is very limited and/or large volumes of yard waste require handling. Leaves are normally placed in a grinder then mixed with grass clippings and formed into windrows. Brush is often separated and chipped to form a mulch. Windrows are aerated either by forced pressure or by daily turning with specialized machines. Piles are continually monitored for temperature and moisture content. A compost can be produced in 6 to 12 months. Compost is often screened to remove stones, plastic, metals, and other undesirable materials to make the product more valuable. High-tech processing sites are often paved, and portions of the processing area may be covered by roofs to control moisture. Each acre of active processing activities can handle between 5,000 and 8,000 cubic yards of incoming yard waste.

Large-scale yard waste composting is concentrated in Northern States where large volumes of leaves are produced in the fall and in the Pacific Coast States where large volumes of vegetation are produced nearly all year. All parts of the country have at least some composting activities, however.

Some examples of communities with yard waste composting programs are as follows:

- Grimm's Fuel, Portland, Oregon: This privately owned and operated facility has been processing, yard waste were from the Portland area since the late 1970's. The City of Portland provides marketing assistance. Over 12,000 tons of yard waste were received in 1986. Grimm's uses a high-tech approach by grinding and sorting materials before composting. The site is too small (11 acres) and numerous equipment changes have been made. There have also been ongoing problems in dealing with the City, especially regarding assistance to receive more yard waste. Grimm's is regarded as successful and is often cited as a well-run private facility.

- City of Madison, Wisconsin: Owned and operated by the City since 1980, this low-tech facility processes 4,000 tons of yard waste per year. The City collects leaves curbside in the fall and brush curbside every 6 weeks. No specialized equipment is used to process leaves,although brush is chipped. Compost is given away to citizens. The project has operated without significant problems.

- Town of Brookhaven, New York: Since 1976, the Town of Brookhaven has operated two sites for yard waste compost. Leaves are collected curbside. Woody materials are sold for firewood or landfilled. Composting is low-tech with finished product screened before being given to citizens. There have been only minor operational problems such as rodents nesting in plastic bags. At 45,500 tons per year, this is currently one of the largest yard waste facilities. It is estimated to have saved the community between $4 million to $8 million in avoided landfill costs (at $140/ton).

- Ramsey County, Minnesota: This facility is a public system that has operated since the early 1980's. Eight low-tech sites handle about 3,000 tons of yard waste annually.

- Davis, California: This is a privately owned and operated facility composting yard waste from Davis, California. Operating since 1981, the facility handles 4,000 tons of yard waste annually. Separated materials are collected curbside once a week and processed by a medium-tech system.

- Town of Wellesley, Massachusetts: This public facility has operated since 1975. Approximately 2,000 tons of leaves and grass are processed annually using a low-tech approach.

- Philadelphia, Pennsylvania: The city-run facility has operated since 1976. Approximately 4,000 tons of yard waste and zoo manure are processed each year. A medium-tech system is used.

- Dover, Delaware - This city-run system has collected yard debris weekly at curbside since 1976. Dover processes about 500 tons of material annually. A low-tech system is used.

- Maplewood, New Jersey: The longest continuously operating public compost facility in the country (since the 1920's), Maplewood handles about 4,000 tons of yard waste each year. Materials are collected curbside. A low-tech system of processing is used.

Many other yard waste composting facilities are currently operating throughout the nation. These facilities are primarily located in Northern States where the fall of autumn leaves is pronounced. Europe and Canada also have numerous facilities for yard waste composting.

Finished compost is a humus-like soil conditioner. Although it does not contain sufficient quantities of nitrogen to be classified as a fertilizer, the compost does contain a range of major and minor plant nutrients and trace elements essential for plant growth. Finished compost from low-tech facilities may contain plastic from bags, metals from nails, traces of herbicides or pesticides from lawn chemicals, stones, and traces of lead (presumed to be from auto emissions). Control of collecting methods to prevent undesirable materials from entering the process and control of finished products is prefered to avoid residual problems.

Although potential markets for yard waste compost are similar to those discussed earlier for solid waste compost (e.g., nurseries, sod growers, landscapers, parks departments, etc.) yard waste compost is likely to be found more attractive to users including homeowners, than solid waste compost because of the lack of foreign objects such as plastics, some small metal objects, textiles, etc.

d. Incineration/Energy Recovery - Food Waste

Food waste is currently incinerated along with other solid waste at dozens of resource recovery facilities throughout the country. It is convenient to incinerate food waste since it is difficult to separate the material from other wastes. Food waste is combustible but has a low Btu value (approximately 2,000 which is below the average mixed-solid-waste Btu value of 4,500).[7] The combustion of food does not inhibit the function of an energy recovery system nor does it cause hazardous constituents in ash or air emissions. However, the low Btu value of food waste may contribute to inefficient or incomplete combustion which is a potential cause of air emission problems.

e. Incineration/Energy Recovery - Yard Waste

Like food waste, yard waste is also low in Btu value, averaging between 2,100 and 4,000 Btu.[8] Grass clippings, in particular, have a low Btu value. During months when grass clippings or wet leaves are common in the waste stream, the overall Btu value of mixed municipal waste could be adversely affected. Proper operation of energy recovery facilities minimizes this potential problem.

The seasonal variation in yard waste disposal may cause concerns about energy recovery design. The volume of incoming waste may fluctuate by 25 percent over the course of a year in Northern States because of large quantities of yard waste in summer months and virtually none in winter months.

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[7] Wilson, David. Handbook of Solid Waste Management, 1977, p. 37.

[8] Wilson.

f. Landfilling - Food Waste

Food waste is most frequently landfilled in the United States. Landfilling is often considered by communities to be the most economical disposal method. It is convenient to landfill food waste since special collections for separated waste are not necessary. Food waste is not known to contribute to the generation of toxic elements in landfills. However, it does contribute to methane generation and leachate production, both of which can cause substantial long-term operational complications for landfills. Food waste undoubtedly contributes to the BOD content in the leachate, but other waste such as yard waste may contribute significantly more.

g. Landfilling - Yard Waste

As with food waste, most yard waste generated in the United States is currently landfilled. This is due to the economics of landfilling (it is often considered to be the lowest cost disposal option) and the convenience of collecting yard waste along with other wastes rather than separating the material for special collection. Yard waste is a suspected major contributor to methane gas generation in landfills. Yard waste also contributes to leachate production. As mentioned in landfilling of food waste. both methane and leachate generation present significant operational difficulties for landfills. The high volume of yard waste in the waste stream also uses valuable landfill capacity at a time when landfills are becoming increasingly expensive and difficult to site throughout the country.

h. Management Trends

At present, yard waste is most commonly disposed of in landfills. It is also successfully incinerated and composted. However, as landfill costs rise, landfill capacity becomes more scarce, and siting for both landfills and incinerators continues to be more difficult, composting yard waste may become more prevalent. In fact, some areas are even considering a ban on the lanfilling of yard waste. For instance, the State of New Jersey as of September 1988 is banning landfill disposal of yard waste generated in 585 communities in the State. Other states, such as New York and Minnesota, are planning similar bans.

4. PROBLEMS

a. Food Waste

Because of the organic characteristics of food waste, it is one of the most unusual components of the waste stream. Characteristics of food waste can cause potential problems with the options available for handling and processing. Some concerns are

- Low Btu Values: Food waste is successfully incinerated, but the high moisture content may contribute to higher air emissions as a result of incomplete burning.

- Difficult To Separate: Kitchen scraps, restaurant waste, and grocery store waste are difficult to store for more than a couple of days because of odor generation and the potential for attracting pests. Separation is also difficult because food waste is often mixed with other wastes such as paper (napkins, cups, plates) and plastic (utensils).

- Methane and Leachate Generation: Food waste contributes to methane generation and constituents in leachate in landfills.

b. Yard Waste

Characteristics of yard waste are unusual when compared to other components of the waste stream. The most unusual aspect of yard waste is the variation in generation between seasons and regions of the country. This problem and other potential problems for the management of yard waste are summarized below.

- Inconsistent Quantities: Fluctuating composition and quantities of yard waste demand careful planning of incineration and composting facilities. Seasonal variations do not have as significant an impact on landfills.
- Low Btu Values: Incineration of yard waste is conducted successfully throughout the country. Nevertheless, high moisture levels in yard waste inhibit complete combustion and may cause higher air emissions levels.
- Methane and Leachate Generation: Yard waste is suspected of being one of the largest contributors to methane generation in landfills. Leachate production is also aggravated by yard waste landfilling.
- Marketing: Compost produced from yard waste has a reputation of being inconsistent in quality from facility to facility. It may be difficult to receive revenue for inconsistent products and attract long-term market commitments.
- Siting: Odor generation, space requirements, noise, traffic, and run-off potential from compost facilities can cause concern among area residents, which in turn will cause siting problems and public opposition.

- Co-composting: Bacteria, odors, and heavy metals in some municipal sewage sludges can raise concerns over product use as well as the operation of co-compositing. These concerns can drive costs up considerably or limit the marketability of the final product.

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TABLE OF CONTENTS

APPENDIX A

E. TIRES

Page

1. SUMMARY A.E-1
2. VOLUME AND TYPE OF WASTE A.E-1
3. CURRENT PRACTICES A.E-2
    a. Tire Collection A.E-2
    b. Tire Stockpiles A.E-6
    c. Disposal A.E-9
    d. Tire Retreading A.E-9
    e. Tire Recycling A.E-10
    f. Rubber Recycling A.E-11
    g. Energy Recovery A.E-12

REFERENCES A.E-14

APPENDIX A
MAJOR WASTE STREAM COMPONENTS

E. TIRES

1. SUMMARY

Tires might be described as an orphan waste, in that no agency or organization is usually willing to assume responsibility for their disposal. Tire problems have exploded over the past several years as retreading of usable tire casings has steeply declined, and operators of municipal landfills have increasingly sought to preserve their diminishing capacity by excluding tires. With fewer and fewer facilities willing to accept tires for disposal, the vast majority of tires wind up in unregulated storage piles where they provide ideal breeding grounds for mosquitoes and, because of the risk of ignition, pose an enormous threat to the environment.

2. VOLUME AND TYPE OF WASTE

In 1986, 220 million tires were discarded, a rate of one tire per person per year.[1] There are three classifications of tires:

- Passenger car and light truck tires account for about 80 percent of the total number of tires scrapped. These 176 million tires, with an average weight of 23 pounds, total 2 million tons or about 1.3 percent of the total municipal waste stream. Another 10 percent of this type of tire is recapped. Almost all recapping of passenger car tires is done for fleet operators.

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[1] La Roe, John. "Tired of Those Roadside Distractions?" Solid Waste and Power, February 1988, pp. 20-22, 25.

There is very little reuse or recovery of the remaining tires; since so many landfills refuse to accept them, most tires wind up in stockpiles. These tires are generated at independent tire retailers, department stores, service stations, and automobile dismantlers.

- Bus and truck tires are generally retreaded if the tire casing is still usable. Nonetheless, about 34 million truck tires were scrapped in 1986.
- The remaining 10 million tires scrapped in 1986 were off-road tires for airplanes, construction equipment, and agricultural equipment.

The typical tire contains 25 percent natural rubber; 25 percent steel; 25 percent synthetic rubber (primarily styrene-butadiens); and 25 percent other materials such as carbon black, fabrics, and inert filters. Its heat value is about 15,500 Btu/lb or about three times the value of mixed municipal solid waste. Table A.E-1 lists the physical and chemical properties of a representative sample of scrap tire materials that are free of bead and cord wire. A chemical analysis of trace elements found in rubber tire ash is shown in Table A.E-2.

3. CURRENT PRACTICES

a. Tire Collection

Scrap tires come primarily from tire dealers and recappers. Tire manufacturers and marketers (such as major oil companies) do not generally make provisions to dispose of tires from their individual outlets. Instead they leave it up to the retailers to arrange for disposal of their own tires. Retailers have to rely on the services of a "tire jockey" to pick up the tires and take them away. Tire jockeys are typically small independent

TABLE A.E-1
PROXIMATE, ULTIMATE, AND METAL ANALYSIS OF BEAD- AND CORD-FREE SHREDDED SCRAP TIRES

Proximate Analysis	% by Weight as Received	% by Weight Dry Basis
Moisture	0.62	-
Ash	4.78	4.81
Volatile Matter	66.64	67.06
Fixed Carbon	27.96	28.13
	100.00	100.00
Ultimate Analysis		
Moisture	0.62	-
Ash	4.78	4.81
Carbon	83.87	84.19
Hydrogen	7.09	7.13
Nitrogen	0.24	0.24
Sulfur	1.23	1.24
Oxygen (by difference)	2.17	2.39
	100.00	100.00
Mineral Analysis		
Zinc Oxide	1.52	1.53
Iron	2.52	2.54
Calcium	0.378	0.379
Chlorine	0.149	0.150
Chromium	0.0097	0.0087
Fluoride	0.0010	0.0010
Cadmium	0.0006	0.0006
Lead	0.0065	0.0065
Heat Value	Btu/lb	kJ/kg
HHV	16,250	37,798
Hv_{ae}	15,500	36,053
TDF Combustion	°F	°C
Tires Ignite	550-650	288-343
Carbon Begins to Burn	842	450
Carbon Completely Burnt	1,202	650

TABLE A.E-1 (con't)
PROXIMATE, ULTIMATE, AND METAL ANALYSIS OF BEAD- AND CORD-FREE SHREDDED SCRAP TIRES

Miscellaneous Properties

Bulk Density Minus 2" TDF	34-37 lb/ft^3
Minus 1 1/2" TDF	34-37 lb/ft^3
Minus 3" TDF Chips w/Wire	35-38 lb/ft^3
Specific Gravity of Tire Rubber	1.05-1.15

Source: Waste Recovery, Inc. "Waste Tire Collection and Incineration Study, Interim Report," prepared for the Minnesota Pollution Control Agency, June 1985.

TABLE A.E-2

TRACE ELEMENT ANALYSES OF SCRAP TIRE ASH
(Moisture-Free Steel-Wire-Free Basis)

ELEMENT	PARTS PER MILLION	
	SAMPLE 1	SAMPLE 2
Barium	47	73
Zinc	24,000	26,660
Cobalt	44	197
Boron	3	6
Lead	50	18
Iron	21,410	1,538
Cadmium	1	1
Tin	256	--
Arsenic	1	1
Calcium	5,610	36
Copper	82	80
Sodium	1,360	254
Potassium	442	205
Mercury	0.01	0.01
Selenium	4	2
Antimony	132	1

Source: Smith, Michael S. "Using Scrap Tires as an Industrial Energy Source," Georgia Tech Research Institute, report for the Georgia Tire Dealers Association, November 9, 1984.

operators with only one truck or very few trucks. While many dealers recognize that their tires may not be going to appropriate disposal facilities, they assume no responsibility for the tires once they leave their property. Increasingly, dealers must pay the jockeys to take the tires, with prices ranging from 50 cents ($40/ton) to as much as $10 ($800/ton) per tire.[2]

The tire jockeys separate resalable (called "high treads") and recappable tires (casings) and then dispose of the rest. In most areas of the country, tire jockeys are neither licensed nor restricted as to where the tires must be taken. Economics prevail, and tires are typically disposed of wherever the cost is cheapest. Quite often this is on private property where the owner is paid to store the tires for "eventual use" as a raw material in an as-yet unbuilt plant. While some stockpilers believe that the high Btu value of the tires ensures their eventual use as a fuel, it is also obvious that if stockpilers claim the tires are a raw material waiting to be recovered, they can often escape regulation as a disposal facility. In other instances the tires end up on remote sites where absentee landowners are entirely unaware that their property is being used.

b. Tire Stockpiles

The location and size of these piles are not well documented, but the tire industry estimates that there are between 2 and 3 billion tires in tire piles scattered throughout the country and that these piles are increasing by 150 to 200 million tires per year.[3] Documenting this figure is difficult because the tire jockeys are usually very secretive about where they take tires. Eliminating a pile is even more difficult because too much pressure on the pile owner might encourage him to take the easy way out by allowing the pile to "accidentally" catch on fire.

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[2] Burgess & Nipple, Ltd., and Waste Recovery, Inc. "Used Tire Recovery and Disposal in Ohio," prepared for the Ohio Environmental Protection Agency, March 1987.

Tire piles pose a serious threat to both public health and the environment. Studies have shown that mosquitoes breed in tire piles at a rate 4,000 times that at which they breed in a natural woodland setting.[4] Entomologists are especially concerned about the Aedes Albopictus or the asian tiger mosquito. This mosquito was first discovered in the United States in 1985 in a tire pile in Houston, Texas, and has since spread to at least 14 states.[5] The mosquito is expected to become a major vector in most states east of the Rockies. This mosquito is of particular concern because it has proven to be a "competent transmitter of dengue fever, and it has the capability to transmit encephalitis. It is also an aggressive biter and has the ability to pass a virus on to its offspring so it can quickly spread a disease in epidemic proportions." One study has shown that "80 percent of the children afflicted with LaCross...Encephalitis (which causes brain damage in children) live within 80 yards of a tire pile" (mosquitoes have a flight range of 500 yards).[6]

Tires represent an environmental concern because of fires that have occurred in a number of locations around the country. In Winchester, Virginia, a 4-million-tire pile ignited in October 1983. It took 8 months and the combined efforts of the Federal, State and county governments to contain the fire, and it ultimately had to burn itself out. Emissions from the fire were visible 200 miles away. The U.S. Environmental Protection Agency (EPA) sent $1.2 million under the Superfund program to contain and remove the oily residue generated by the burning tires.[7] Other major tire fires have occurred recently in Denver, Colorado, and Everett, Washington (where the cost to fight the fire exceeded the entire annual budget of the local fire department).

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[3] Hershey, Robert L., et al. "Waste Tire Utilization," prepared by Science Management Corporation, Washington, D.C., for the U.S. Department of Energy, April 30, 1987.

[4] LaRoe.

[5] Hall, Stephen S. "The Invader," Hippocrates, September/ October 1987, pp. 36-45.

[6] LaRoe.

Tire stockpiles may contain anywhere from just a few hundred tires to as many as 40 million tires. The latter number represents the size of a tire pile in Modesto, California. These tire piles are usually not regulated and as such are not subject to any provisions to prevent them from becoming a major environmental hazard. Efforts to force tire stockpilers to limit the size of individual piles; separate the piles by all weather fire roads; and provide items such as fencing, fire control measures, and spray for mosquitoes have largely been unsuccessful.

Efforts to eliminate the tire piles have also been largely unsuccessful. The pile in Modesto, California, was recognized as a major threat to the agricultural base in the Salinas Valley. In an effort to eliminate the pile, the State supported the construction of a $38 million dedicated tire combustor that would generate electricity for sale to Pacific Gas & Electric. (This process is discussed in more detail below.) The plant was built with the understanding that its "fuel" would be drawn from the existing tire stockpile at a rate of 4 million tires per year.

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[7] VanderMeulen, Joe, and Loanne Ammerman. "Scrap Tires, Recovery and Disposal," Michigan Legislative Service Bureau, September 1985.

c. Disposal

Some landfills do accept tires. However, most landfills are unwilling to accept tires, because they are difficult to handle and take up a lot of space. The most common problems are that they tend to rise or float to the surface, and they create voids in the landfill, which tend to harbor rodents and cause uneven settling.

At several landfills and incinerators, equipment has been installed to shred or slice the tires. Once this is done, the smaller pieces can be mixed in with the municipal waste. There are at least 20 companies manufacturing tire shredding or slicing equipment, but the number of municipal waste sites equipped to process tires is not known. Shredding of tires can cost as much as $30-$50 per ton.

Landfills that do accept tires will sometimes set the disposal fee significantly higher than for the other wastes, and often at a level high enough to discourage tires from being brought to the facility. This is the case in Delaware where the Delaware Solid Waste Management Authority set the fee for mixed municipal waste at $36.25 per ton and at $70.00 per ton for tires. At about $.90 per tire, this fee discourages most tire jockeys from using the Delaware sites.

d. Tire Retreading

Tire retreading has a limited and diminishing role in the management of scrap tires. Retreading has been declining for the past two decades and in 1987 represented only 8 percent of passenger tire sales (16.5 million tires).[*] Currently, retreading is almost exclusively done for heavy trucks and buses, for off-road vehicles, and for fleet operations among passenger cars and light trucks. More than one-third of all replacement tires for trucks, and two-thirds for buses are retreads. Demand for retreadable truck casings is sufficiently strong that retreaders import truck tire casings from abroad to augment the available domestic supply of suitable casings. The tire industry claims that the quality of truck tire casings is continuously improving so that they can be retreaded more times before being scrapped.

There is virtually no retail-consumer market for retreaded tires because they cannot compete economically with cheap imports. The entry-level price for a retread is about $22, while new imports begin at about $27. Even though the retread may give longer mileage, the market segment for the least-expensive grades of tires does not generally consider cost per mile when selecting a tire. There is a limited export market for retreadable tire casings in Mexico, but shipping costs limit the draw to Texas and Southern California. Opportunities for exporting retreaded tires and tire casings to other countries have not been fully explored.

e. Tire Recycling

There have been numerous efforts around the country to use scrap tires as fishing reefs, erosion control barriers, dock bumpers, swings, and so forth. Programs such as these are usually promoted as a one-shot effort to eliminate accumulated tires or for their public relations value. Their total impact on the tire problem is minimal. Neither the economics nor the market capacity can absorb recycled tires on a continuous, long-term basis.

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[*] Modern Tire Dealer. "1987 Tire Industry Facts," Modern Tire Dealer, January 1988, pp. 40-54.

f. Rubber Recycling

There have been numerous efforts undertaken to recycle the rubber in scrap tires. These range from slicing tires into smaller pieces that can be used to make floor mats, fan belts, or muffler hangers, to processes like the TireCycle that shreds and granulates the rubber into very fine particles that are than heated and mixed with chemical polymers to make a rubber product that can be molded into new products. TireCycle was financed by the State of Minnesota to process tires for recovery after it prohibited them in landfills.

None of the product lines identified so far have the ability to use a significant quantity of recycled rubber. In addition, tire manufacturers claim that the use of synthetics and the special requirements of the high-performance tires now being produced preclude the use of scrap rubber in the manufacture of new tires.

One use that does have the capacity to absorb significant quantities of recycled rubber is as an additive for asphalt paving. Test programs using shredded rubber additives for asphalt paving have been conducted in a number of states with promising results. However, the advantages of longer life have not been proven to outweigh the increased costs and extra care that is involved in using asphaltic rubber. Some state highway-maintenance officials claim that the presence of rubber in the asphalt prevents the use of the newer, in situ repaving processes that are now available.[9] The Asphalt Institute has opposed the use of rubber additives for this reason. Smaller amounts of recycled rubber can be used in asphalt crack sealants.

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[9] Wilson, Donald, of National Tire Dealers and Retreaders Association, Washington, D.C. Personal communication, March 25, 1988.

g. Energy Recovery

While not an ideal fuel with regard to physical handling or ease of combustion, tires are a high Btu material. At 15,000 Btu/lb, tires have three times the energy value of municipal solid waste and are about equivalent to the heat value of high-grade coal. Because of this, there have been a number of efforts to burn tires to tire-derived fuel (TDF) both in this country and elsewhere. Most of these efforts have achieved only limited success. The major problems inhibiting more use of TDF are the lack of a sufficient, reliable supply and marginal economic benefit. Because of the marginal benefits derived, potential users are often reluctant to consider using TDF.

As previously mentioned, the most ambitious effort at burning tires is currently underway in Modesto, California. The fact that the adjacent stockpile of 40 million tires ensured a 10-year supply of fuel for the facility encouraged the financial community to support the project. California has an Alternative Energy Law that ensures high revenue for the electricity produced at the plant. This fact is especially important because the project will not receive any revenue for the tires that are burned. The plant has only recently received its operating permit. Oxford uses the German Gummi-Mayer process to burn the tires. This process consumes 800 tires per hour and will generate 14mw of electricity. Its technical, economic, and environmental viability must still be documented. The owner and operator of the plant, Oxford Energy Company, is attempting to build additional facilities in other locations, including one in Sterling, Connecticut, that would draw feedstock from several New England tire stockpiles.

There have been numerous efforts to market TDF as a supplemental fuel in existing furnaces and boilers. A leading company in the effort to develop this concept is Waste Recovery, Inc. of Dallas, Texas. Their approach is to shred tires into small particles that can than be shipped to various customers for use in their existing furnaces. Unfortunately, currently depressed energy markets threaten the economic viability of this approach.

Another impediment to marketing TDF is that it is difficult to reliably supply enough fuel for most potential users to justify the cost of modifications needed to accommodate the TDF. For instance, cement kiln have been identified as one of the more promising markets for TDF. However, substitution of 20 percent of the energy demand for a single average-size kiln would require 5,000 tires per day, or all of the tires produced by a population of between 1.5 and 2 million people.[10] Because of these problems, it is difficult for companies like Waste Recovery, Inc., to generate interest in its TDF. In addition, they must overcome user concerns about emissions, possible damage to furnace grates and refractories, storage and disposal problems community opposition, and potential increased surveillance by local enforcement agencies.

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[10] Smith.

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E. TIRES

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9. Waste Recovery, Inc. "Waste Tire Collection and Incineration Study, Interim Report," prepared for the Minnesota Pollution Control Agency, June 1985.

10. Wilson, Donald, of National Tire Dealers and Retailers Association, Washington, D.C. Personal communication, March 25, 1988.

TABLE OF CONTENTS

APPENDIX A

F. BATTERIES

Page

1. INTRODUCTION A.F-1

2. HOUSEHOLD BATTERIES A.F-1
    a. Source and Volume A.F-1
    b. Disposal Stream A.F-5
    c. Toxic Potential A.F-5
    d. Household Battery Recycling Problems A.F-10

3. AUTOMOBILE LEAD-ACID BATTERIES A.F-11
    a. Source and Volume A.F-11
    b. Disposal Stream A.F-15
    c. Market Future A.F-20

REFERENCES A.F-21

APPENDIX A
MAJOR WASTE STREAM COMPONENTS

F. BATTERIES

1. INTRODUCTION

There are two major types of consumer batteries used in the United States: household batteries and lead-acid batteries. Household batteries are used in a variety of applications including flashlights, radios, toys, shavers, photographic equipment, hearing aids, and cordless power tools. Lead-acid batteries are used in automobiles, motorcycles, lawnmowers, and other equipment requiring large power. Each type of battery can be purchased in many ways including retail stores, discount stores, drug stores, and mail-order catalogs. In general, spent household batteries are not recycled but are discarded directly into the municipal solid waste (MSW) stream. Spent lead-acid batteries, which used to be recycled at a very high rate, are now being discarded into the MSW stream or with junked automobiles (see Appendix B.C) at an increasing rate.

2. HOUSEHOLD BATTERIES

a. Source and Volume

The average American household will buy over 28 household batteries this year.[1] The Census Bureau estimates 90 million households in the United States in 1988, which amounts to more than 2.5 billion total household batteries sold in the United States.[2] Various types of household batteries are in common use, each representing a different system of chemical materials (positive electrode, negative electrode, and electrolyte). The most common are summarized below.

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[1] The FUTURIST, November-December 1986.

[2] Census Bureau. Statistical Abstracts of the United States, U.S. Government Printing Office, Washington, D.C,, 1987.

Mercury cells are widely used in electrical appliances, such as hearing aids, that require the high energy-to-volume ratio provided by these cells. Their mercury content can be 35 percent by weight. The cells can be button or cylindrical in shape and can consist of an energy system of zinc/potassium/mercury oxide. In the button-type cells, the case constitutes the positive terminal, while in the cylindrical cells a separate button that is set into the base of the battery will constitute the positive terminal.

Cylindrical alkaline-manganese batteries are similar in construction to cylindrical mercury batteries. They can provide comparatively heavy currents and have good storage properties. They are widely used to power flashlights, toys, and similar items. The system consists of zinc/potassium hydroxide/manganese dioxide. The batteries also contain about 7 percent mercury by weight. The mercury is not used for energy but rather to control the natural tendency of the zinc negative electrode to react with other battery components and generate a gas that greatly reduces the performance of the battery. By including a small amount of mercury on the surface of the zinc, the battery industry has been able to control the undesirable gas generation. Used in this way, mercury extends the shelf life and enhances the battery performance.

Historically, zinc-carbon batteries based on the Leclanche cell are the original dry-cell battery. They find use in a variety of portable electrical appliances, and their comparatively low cost allows them to compete with high-performance cells. The system consists of zinc/ammonium chloride/manganese dioxide, and these batteries come in both cylindrical and flat cell shapes. They may also contain a small portion of mercury to stabilize gas generation by the zinc.

Silver-oxide batteries are generally produced as button cells with over 30 different sizes. These cells are used to power very small appliances such as watches. The system is silver oxide/potassium hydroxide or sodium hydroxide/zinc. They also contain about 1 percent by weight of mercury.

Zinc-air batteries are a relatively new product developed after years of research. The system is zinc/potassium hydroxide/oxygen with the oxygen supplied by air through holes in the casing; the holes are sealed with a removable foil until the battery is needed for use. Once the foil is removed, the cell discharges relatively quickly and for this reason it is used mostly for continuous discharge applications such as hearing aids. Thought of as a replacement for mercury-oxide batteries, the zinc-air battery uses considerably less mercury and lasts about twice as long as its mercuric-oxide counterpart. Unfortunately, however, the use of outside air can cause the performance of the zinc-air battery to vary unreliably, depending on the balance of moisture and oxygen in the air. For this reason the zinc-air battery will not likely be a complete replacement of mercury-oxide batteries for a number of years.[3]

Nickel-cadmium (sometimes referred to as "NiCad") batteries are the only kind of rechargeable battery. The battery can be recharged up to 1,000 times and can be used for several years before disposal. The system consists of cadmium hydroxide/potash lye/nickel hydroxide. The batteries come in button, cylindrical, and rectangular shapes. In general, 75 to 80 percent of the nickel-cadmium batteries sold are currently sealed inside the cordless rechargeable appliances they power.

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[3] National Electrical Manufacturers Association (NEMA). Correspondence.

Lithium batteries are still being developed and their importance in commercial applications is currently small. These batteries, which use a system of lithium and a variety of other chemicals (such as manganese dioxide), have been used to power pocket calculators and wrist watches.

Of the types of household batteries available, carbon zinc and alkaline manganese have the biggest share of the market (approximately 90 percent). The use of zinc-carbon batteries is decreasing while the use of alkaline-manganese batteries is on the rise.[4]

Mercury-oxide batteries are in less demand than in the past, whereas silver-oxide and nickel-cadmium batteries are becoming more and more popular.[5] Only moderate rates of growth are predicted for zinc-air and lithium batteries until they are perfected.

Overall, the demand for household batteries is expected to continue increasing with the trend toward a higher demand for high-performance, long-life batteries. It is unlikely, however, that any of today's common batteries will completely disappear from the market.[6]

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[4] Organization for Economic Co-Operation and Development (OECD). "Fate of Small Quantities of Hazardous Wastes," OECD, Economic Monograph #38057, 1986.

[5] OECD.

[6] OECD.

b. Disposal Stream

Although some states are investigating legislation for household battery recycling, there are presently no Federal or State regulations concerning disposal of household batteries.[7] Some commercial recycling of household batteries exists (particularly for silver recovery); however, in essence, virtually all spent household batteries are discarded into the household solid waste stream and end up in MSW facilities.[8]

c. Toxic Potential

Mercury and cadmium are the primary constituents of household batteries that are of concern, because of their potential for release from landfills or incinerators.

The amount of mercury used in household battery production is shown in Figure A.F-1. The real and predicted decline in use is a result of continuing research by the U.S. battery industry in finding ways to reduce the amounts of mercury used in batteries (both for economic and environmental reasons). The industry predicts that the decline in mercury use will continue well in the 1990's.[9]

According to the U.S. Bureau of Mines, 1,001 tons or 27 percent of all the cadmium used in the United States in 1984 went into the production of batteries. Of all of the cadmium contained in nickel-cadmium batteries used in the United States, approximately 75 percent of the cadmium is in batteries used by consumers.

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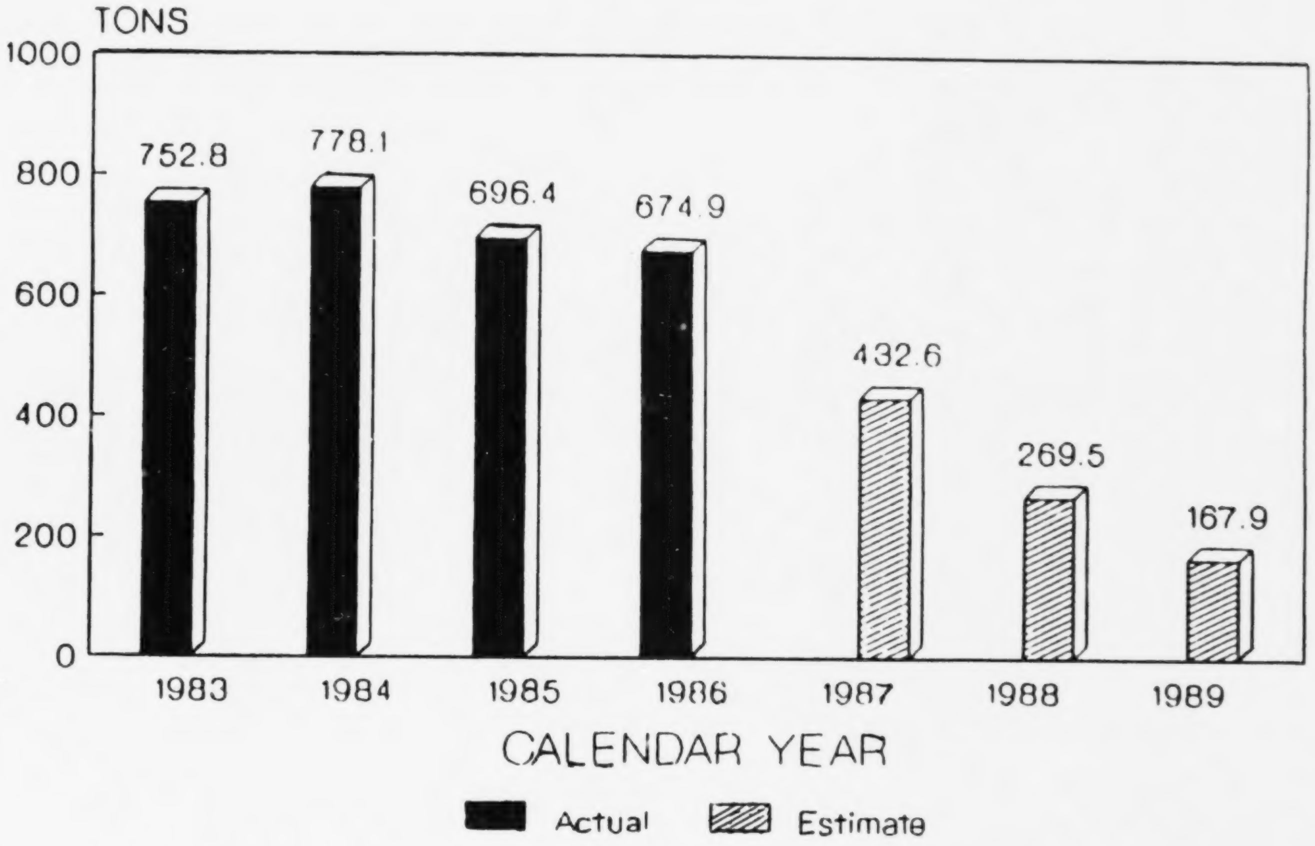
[7] NEMA correspondence.

[8] Cowen, David, of Mercury Refining Company, Inc. Personal communication, May 1988.

[9] NEMA correspondence.

FIGURE A.F-1

MERCURY USAGE IN U.S. CONSUMER BATTERY PRODUCTION



4/1/87

Approximately 75 to 80 percent of the nickel-cadmium batteries used by consumers are built into appliances, and the appliances would have to be broken open to remove the batteries. Only the remaining 20 to 25 percent of the batteries are ones that consumers can easily replace. If consumers recycled all of the nonsealed nickel-cadmium batteries, the result would be recycling of only 15 to 19 percent of the originally produced nickel-cadmium batteries. This figure equates to a recycling of approximately 150 to 185 tons of cadmium annually or about 4 to 5 percent of the U.S. total cadmium usage.[10]

Currently, very little research data are available regarding the actual threat posed by discarded mercury and cadmium batteries to ground water or air. One of the few studies conducted in the United States determined that batteries recovered from a landfill site after 7 months of burial were less corroded than those exposed to anaerobic leachate for 3 months in a laboratory.[11] The study postulated that the reason for this is that, in a landfill, a conducting pathway between the battery terminals may exist only intermittently, if at all. This condition reduces the ability of residual charge in the battery to contribute effectively to the corrosion process. Furthermore, the study determined that "analyses of the leachate from the tests showed that only a very small proportion, if any, of the mercury, cadmium, nickel, or silver present in dry-cell batteries was dissolved by the leachate."

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[10] U.S. Bureau of Mines. 1984 is the latest year for which the Bureau of Mines has published data.

[11] Jones, et al. "An Investigation of the Degradation of Some Dry Cell Batteries Under Domestic Waste Landfill Conditions," Journal of Hazardous Materials, 1977-1978, pp. 259-289.

According to this study:

> ...field studies have shown that, although zinc and manganese may be leached from large deposits of Leclanche cell wastes, there is no evidence that mercury is leached from landfilled material to any significant extent or that organo-mercury compounds are formed. Both the laboratory and field investigations indicate that, provided they are well mixed with household wastes and recommended disposal practices are employed, the presence of domestic arisings of primary dry-cell batteries in landfill presents no special threat to groundwater quality.[12]

While it did not focus specifically on the impact of dry-cell batteries in sanitary landfills, a more recent study of hazardous household waste in landfills, presented in January 1988, provided the following observations concerning household batteries:[13]

- Many dry cell batteries were identifiable after 5, 6, and 10 years in sanitary landfills.
- These batteries were in different states of decomposition.
    - Some batteries looked like new.
    - Some batteries were partially corroded to expose a part of the interior dry-cell contents.
    - Some batteries were almost totally degraded to the point that they were difficult to identify.
    - There were many different sizes and types of batteries.
    - No particular degree of degradation could be attributed to a particular kind of battery. Some wet-cell car batteries were totally intact.
- Batteries were no different from a lot of other items, which were in various stages of degradation caused by the landfill environment.

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[12] Jones, et al.

[13] Kineman, R., and D. Nutini. "Hazardous Household Waste in the Sanitary Landfill," Fourth Annual Conference on Solid Waste Management and Materials Policy, January 30, 1988.

- No particular detrimental impact was noticed for any of the batteries.
- The weight of batteries relative to the total weight of refuse was small.

Outside the United States, Japan scientifically investigated the environmental problems caused by disposal of household batteries and decided not to legislate household battery recycling but to strongly urge such recycling through a public awareness program. Based on scientific measurements at landfills and incinerators, this decision determined household batteries were not a health threat. The decision was also based on the fact that mercury in household batteries has been drastically reduced in the past few years and should be reduced even further because of current research and development (R&D) and the introduction of the mercury-free, zinc-oxide battery.[14]

Sweden has legislated a household battery collection program; other European countries such as Denmark, France, Germany, the Netherlands, and Switzerland have established voluntary recycling collection programs and urge the public to use them. While these batteries are collected separately, they are not recycled. Rather, they are disposed of. Each of these programs, however, is based on public concern and not on scientifically collected data proving that household batteries cause a hazard.[15]

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[14] Hershkowitz, A., and E. Salerni. Garbage Management in Japan: Leading the Way, INFORM Inc., No. ISBN 0-918780-43-8, New York, 1987.

[15] OECD.

d. Household Battery Recycling Problems

Establishing a household battery recycling chain is complicated by the following factors:

- It is only marginally economical to recycle mercury-oxide batteries and so the marketplace cannot be relied on to recycle them.
- It is very difficult to recognize mercury-oxide batteries from other types of batteries; therefore, the consumer cannot be relied on to separate them. This could be changed if battery manufacturers were required to clearly mark mercury-oxide batteries by color or other coding.
- It is economical to recycle silver-oxide batteries (and recover the mercury), but only if they are collected separately and not contaminated by the presence of other types of batteries. Separate collection leads to a battery identification problem and/or labor-intensive sorting problem at the recycle plant. Japan found the labor intensive sorting processing to be economically impossible.[16]
- Most nickel-cadmium (rechargeable) batteries are sealed in the appliances they power and require the consumer to break open the appliance to recycle the battery. This is not a very feasible requirement.
- Collection in the home of the smaller-sized household batteries awaiting recycling has been raised as posing a significant threat of ingestion to infants and elderly people. Fearing this fact, the Director of the National Capital Poison Center in 1987 wrote to members of the New York State legislature to oppose a bill requiring deposits on two kinds of household battery button cells.[17]
- The processing of used batteries results in residues that must be disposed of in hazardous waste facilities.[18]

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[16] Herskowitz.

[17] NEMA files.

[18] Cowan.

- o Since today virtually no recycle chain exists for recycling household batteries, a complete system would have to be developed.

3. AUTOMOBILE LEAD-ACID BATTERIES

a. Source and Volume

Approximately 70 million new lead-acid batteries were shipped in 1985, with the number rising to 75 million in 1986 as shown in Figure A.F-2. At the same time, approximately 70 percent of the lead-acid batteries that were spent in 1985 were recycled (see Figure A.F-3). The remaining 30 percent, or approximately 21 million batteries as shown in Figure A.F-4, either entered the MSW stream or went somewhere in the environment at large.[19] One study of a 4,000-ton sample of refuse processed at the Resource Authority of Sumner Country (RASCO) plant in Gallatin, Tennessee, indicated that less than 3 percent of the nonrecycled lead ends up in the MSW stream--the rest (to quote the author) goes, "not in the waste stream, but somewhere."[20]

Lead-acid batteries are approximately 50 percent lead by weight, contain approximately 1 gallon of sulfuric acid (which contains lead byproducts), and are being introduced into either the household waste stream or the environment at large in very large numbers when they are not recycled. If we assume that 21 million batteries are not recycled each year and if we convert this number to lead tonnage at the rate of 17 [illegible] pounds of recoverable lead per battery, 170,000 metric tons of lead are

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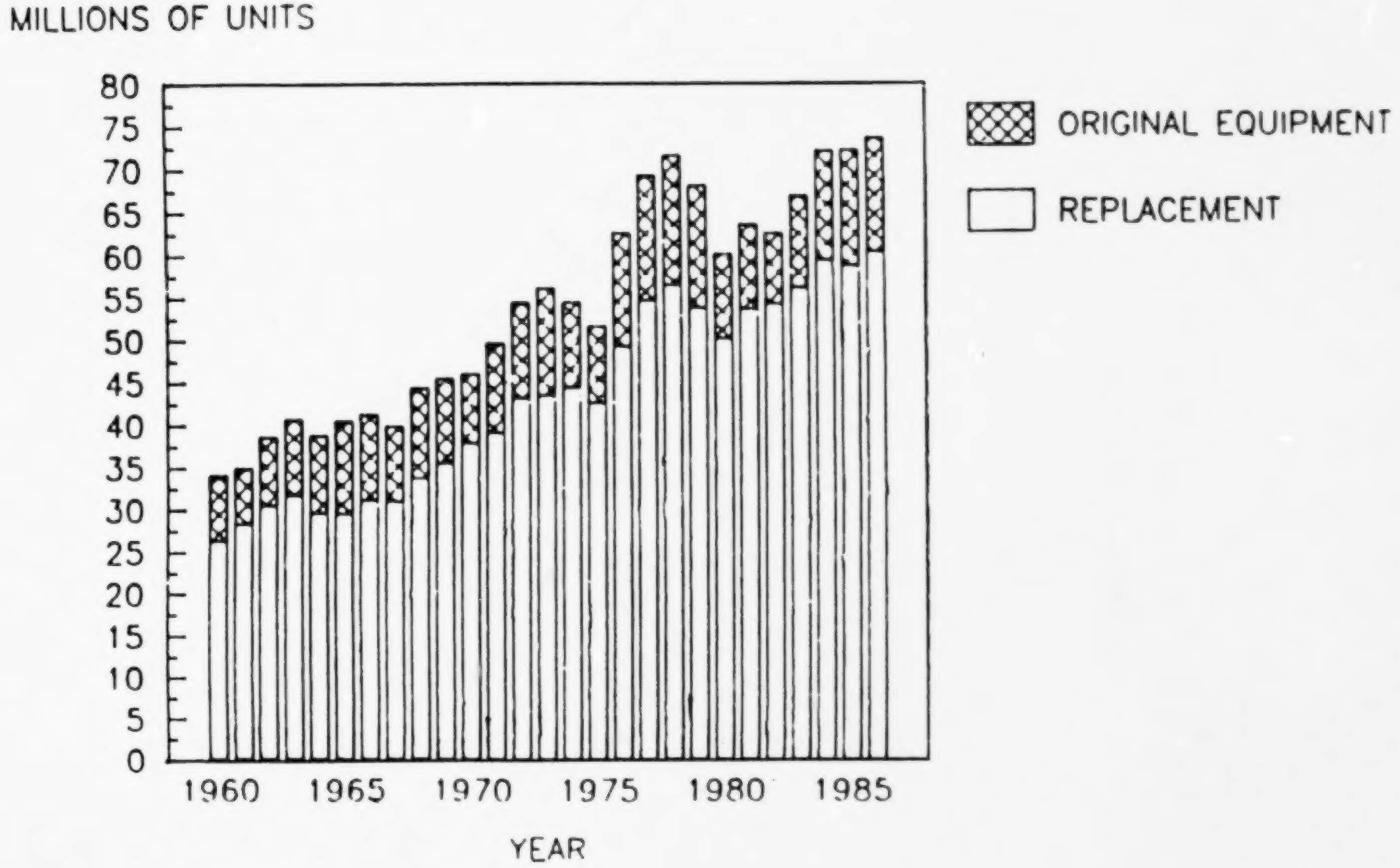
[19] Putnam, Hayes & Bartlett, Inc. "The Impacts of Lead Industry Economics on Battery Recycling," Cambridge, Massachusetts, June 4, 1986.

[20] Roos, Charles E. "Is Lead a Problem?" Waste Age Magazine, February 1988.

FIGURE A.F-2

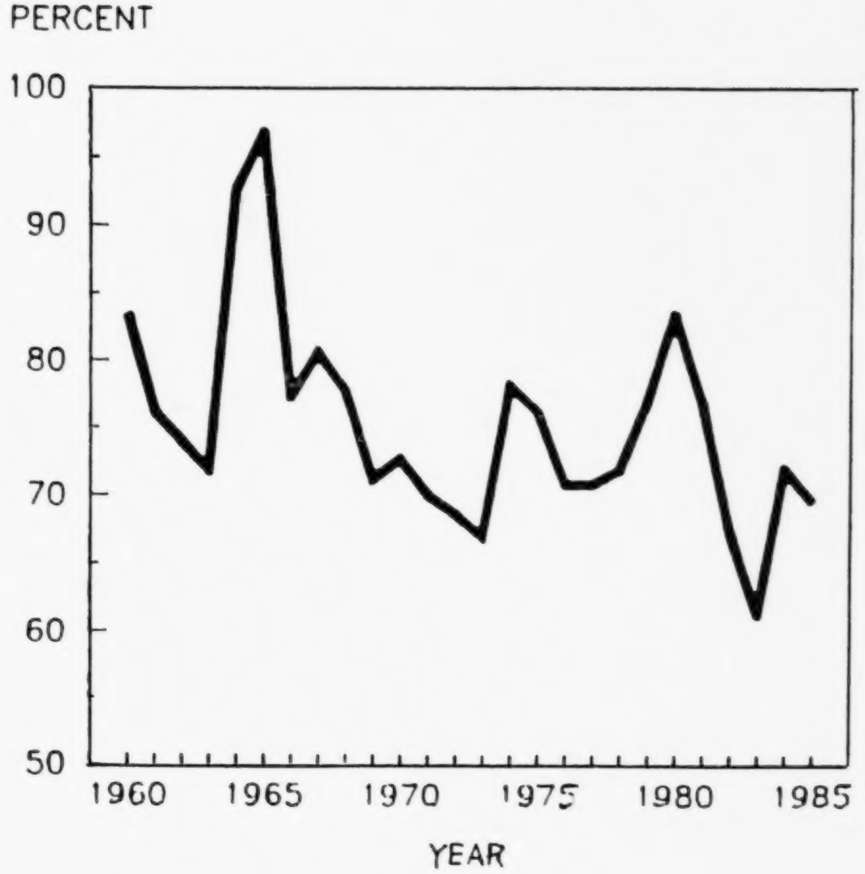
BATTERY SHIPMENTS 1960 – 1986



Source: Battery Council International

FIGURE A.F-3

BATTERY RECYCLING RATES: 1960 - 1985



leaving the recycling chain each year in the United States.

RAM, Incorporated, in a study performed for the Commonwealth of Virginia,[21] stated, that the chief environmental concern with lead-acid batteries was the potential of the lead leaching from the battery and reaching ground water. Excerpts from that study are as follows:

> Lead bearing wastes when disposed of in municipal solid waste disposal facilities can form lead acetates and migrate as leachate from a landfill. Lead is more soluble than most heavy metals and highly soluble in some organic compounds, and more importantly in an acid environment. The natural regime of a landfill s of acid nature thereby presenting the opportunity for lead to leach into solution and migrate from landfills as part of the leachate generated by landfills. This is particularly important when acetic acid is formed in a landfill. [Since] the mechanism by which these acetates migrate is somewhat unknown, the significance of lead in landfills as a contributor to groundwater contamination may be overstated for two reasons, one, it is felt lead acetate will complex with soils, especially clay, which would prevent further movement; and two, scientists believe it is rare for lead acetate to migrate long distances.
>
> Sulfuric acid from batteries, although toxic, would most likely be neutralized by the buffering agents in soil. Therefore, it is the lead drawing compounds in the batteries which are of concern.
>
> The EPA National Priority Listing (NPL) [notes that] lead contamination occurred at a number of sites (55 of 756), but the source of the lead was industrially based (flyash and paint sludges). Furthermore, only one NPL landfill site (GEM's Landfill in New Jersey) showed signs of lead in its leachate and surrounding aquatic environment.
>
> Consequently, it appears that the lead in batteries could be a problem especially in municipal solid waste landfills where the regime is highly acid. Otherwise, the environmental data seems sparse, although lead would become a contaminant in the future if large numbers of batteries reach municipal solid waste disposal facilities or resource recover facilities.

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[21] RAM, Inc. "Current Management Practices for Discarded Lead-Acid Batteries in Virginia," undated.

b. Disposal Stream

The battery recycling chain, as depicted in Figure A.F-5, has been studied by Putnam et al. for the U. S. Environmental Protection Agency (EPA). As they state,

> The recycling chain, shown in [Figure A.F-5] typically works as follows: A consumer returns his spent battery to a battery dealer or service station, who then returns it to a battery distributor and/or scrap dealer. It is then transported to a secondary smelter for battery breaking and smelting. Battery breakers, which separate a battery into its component part (e.g., plastic casing, lead plates, and sulfuric acid), were historically independent operations. However, stringent environmental regulations and poor lead industry economics caused most of the independents to cease operations by 1985. The vast majority of the secondary smelters are currently integrated processors and have their own battery breaking equipment. The recycling chain is complete after the lead from scrap batteries has been smelted and shipped to a battery manufacturer for the production of new lead-acid batteries.[22]

In the early 1960's, when the price of secondary lead was high and when Federal regulations on secondary smelters and all other members of the lead-acid battery recycling chain were minimal, the lead-acid battery recycling rate reached a high of 97 percent as shown in Figure A.F-6. Since that time, lead prices have fallen and so has the recycle rate. however, Putnam et al. have shown that the decrease in the recycled rate is only partly caused by the fall in lead prices; the dramatic increase in environmental regulations and the liabilities of smelters and other members of the recycling chain are also to blame.

Regulations that apply to spent battery handlers include ambient air quality standards for lead, Occupational Safety and Health Administration (OSHA) standards for lead in the workplace, water quality standards for smelters and battery plants, and

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[22] Putnam, Hayes & Bartlett, Inc.

FIGURE A.F-4

NUMBER OF BATTERIES EXITING THE RECYCLING CHAIN

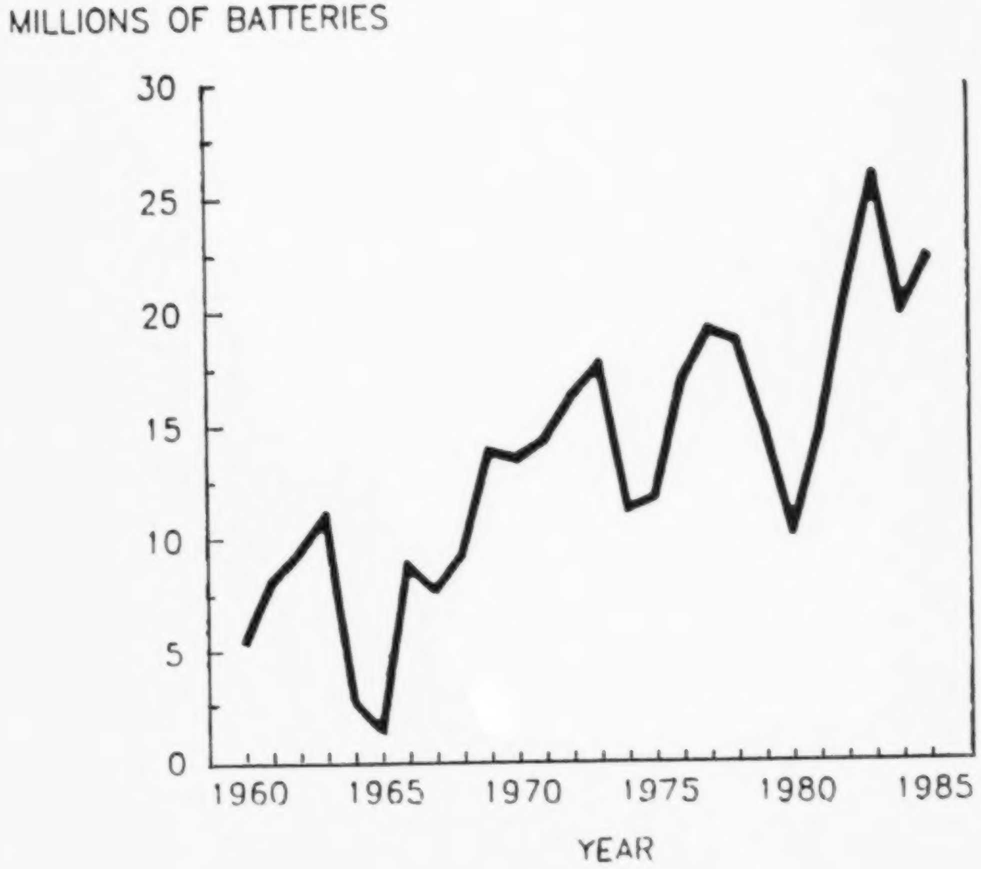


FIGURE A.F-5

BATTERY RECYCLING CHAIN

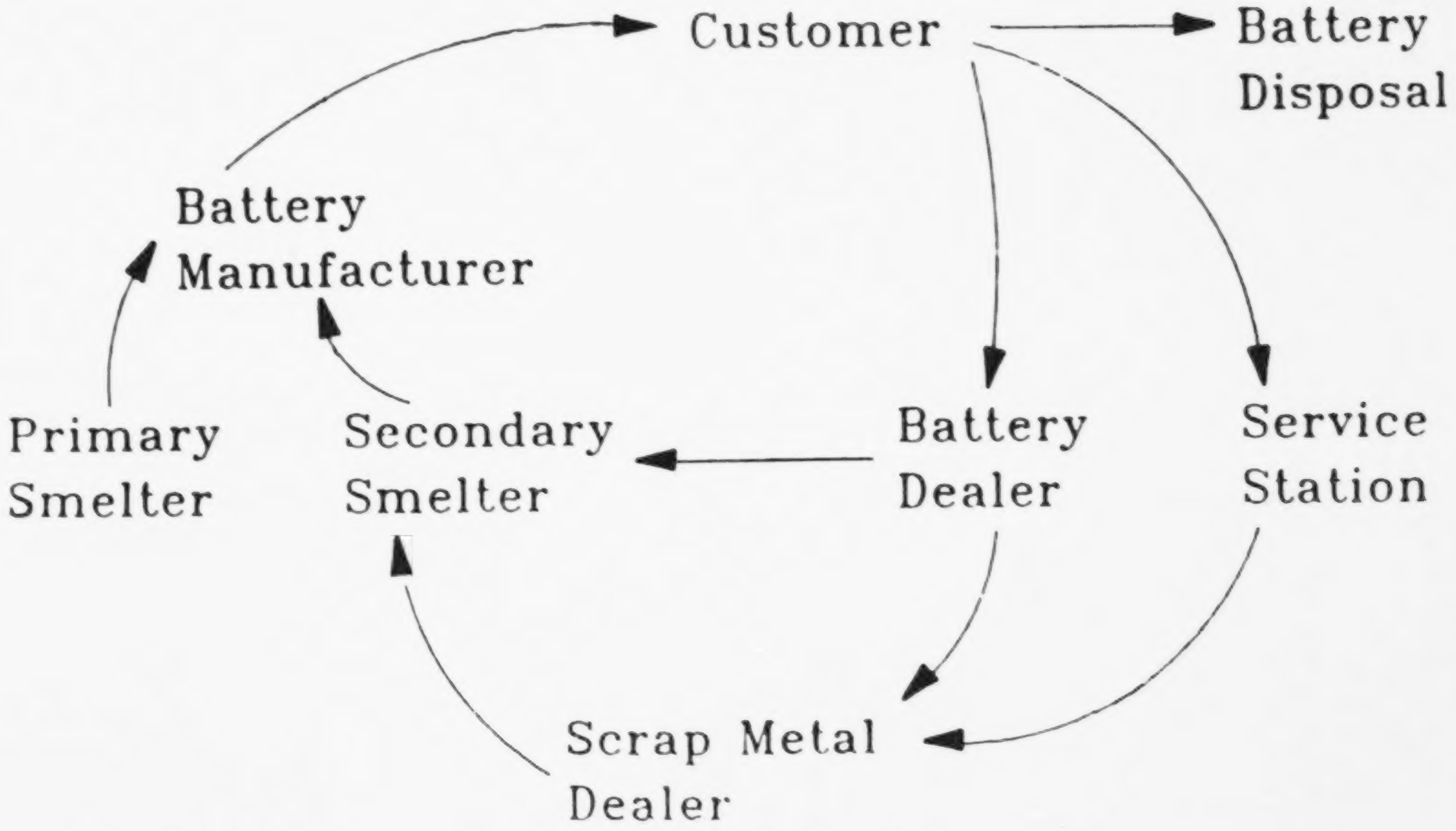
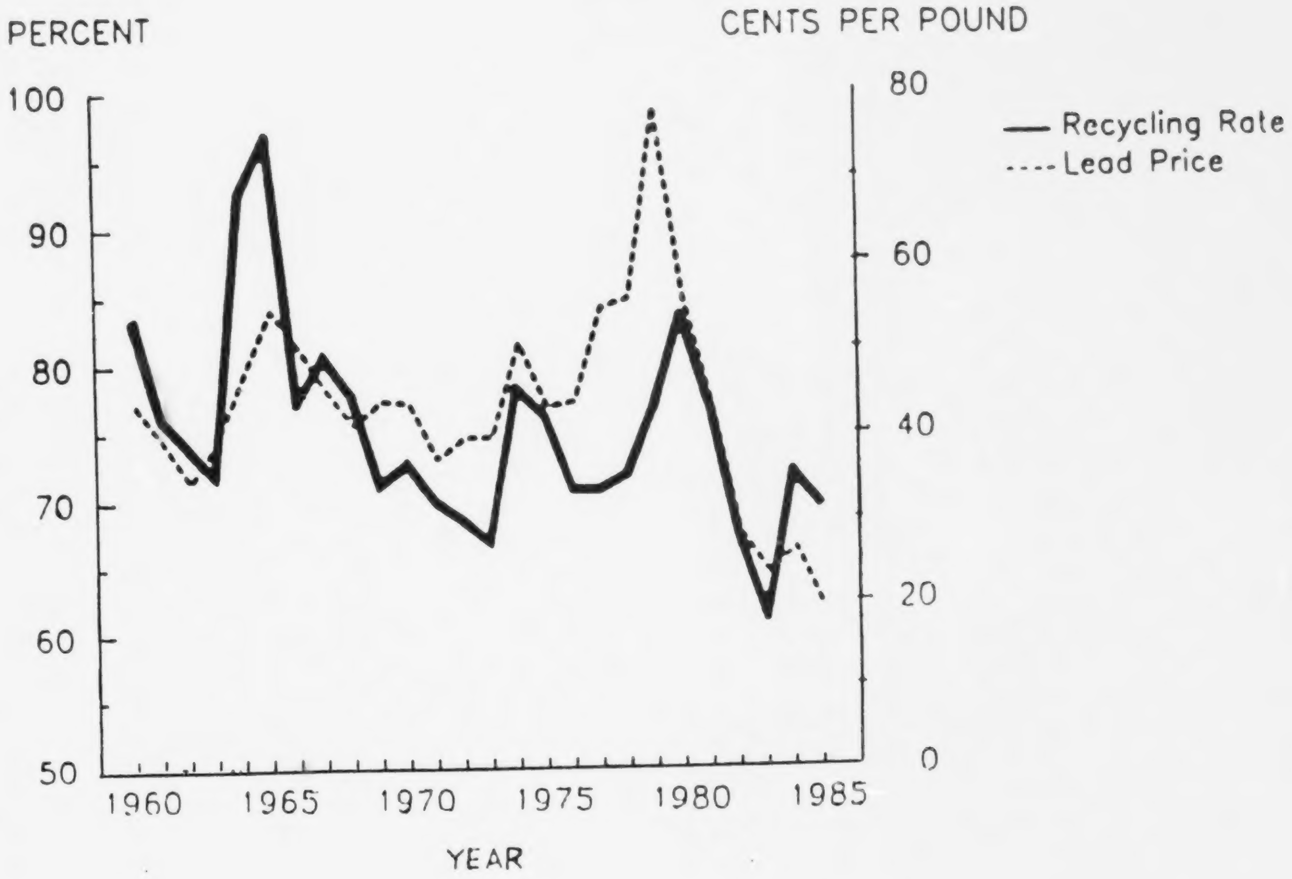


FIGURE A.F-6

BATTERY RECYCLING RATES AND LEAD PRICES



recent Resource Conservation and Recovery Act (RCRA) regulations for the storage and handling of hazardous waste. The costs of RCRA alone to a secondary smelter that handles lead-acid batteries can be between $100,000 and $200,000 per plant.[23] In addition, the nonsudden liability insurance that is also required may simply be unavailable. As pointed out by Putnam et al., "there are many smelters operating as land disposal facilities that have not yet fulfilled the insurance and other requirements necessary to maintain interim status. Stringent enforcement of these regulations could cause continued closures."[24]

Concern over the costs and implications of these regulations plus the possibility of Superfund liability have caused many members of the recycling chain to stop handling lead-acid batteries altogether. For example, the Institute of Scrap Iron and Steel (ISIS) issued a warning to its members about accepting any material that "poses a potential risk to their business." At the 1987 convention, the president of ISIS urged that scrap handlers refuse to accept such material and called the environmental rules and regulations "the gravest issue facing the metal recycling industry."[25] In addition, one smelter in the East reported that 30 percent of its suppliers had dropped out of the scrap lead-acid battery end of the business.[26]

In practice, many retail lead-acid battery dealers are simply refusing to take spent batteries.[27] Consequently, an increasing number of consumers are simply discarding their spent lead-acid batteries into the household waste stream or the environment at large because there is no place else to conveniently dispose of them.

---

[23] American Metals Market, January 15, 1987, p. 1.

[24] Putnam, Hayes & Bartlett, Inc.

[25] American Metals Market.

[26] Sappington, Michael J., of Secondary Lead Smelters Association. Personal communication, May 1988.

[27] Sappington.

c. Market Future

The current demand for lead in the United States is dominated by lead-acid batteries, with leaded gasoline and paint products a distant second and third, respectively. Since the use of lead in gasoline and paint products is predicted to continue to decline significantly, and since there is no substitute for a lead-acid battery on the horizon,[28] lead-acid batteries will continue to be the single most dominant source of lead entering MSW facilities and the environment at large.[29]

In 1985, lead-acid storage batteries accounted for 73 percent of the 1.1 million metric tons of lead consumed in the United States. In contrast, gasoline and paint products totaled only 10 percent of the total lead consumed in 1985; they are expected to consume essentially 0 percent by the end of the decade.

In the absence of new technology, lead-acid batteries represent the only major source of continued growth for the lead industry. Using figures obtained from the Battery Council International, Putnam et al. predicted that "growth in battery sales will act to offset declines in other end uses due to product obsolescence and environmental regulation, and will yield a relatively constant demand for lead into the 1990s."[30]

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[28] Bureau of Mines Minerals Yearbook, Lead Table 12.

[29] Wilber, Robert, of Battery Council International. Personal communication, May 1988.

[30] Putnam, Hayes & Bartlett, Inc.

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TABLE OF CONTENTS

APPENDIX A

G. METALS AND WHITE GOODS

Page

1. INTRODUCTION A.G-1

2. WASTE COMPOSITION AND QUANTITIES A.G-1

3. GRADES AND TYPES OF SCRAP METAL A.G-4
    a. Home Scrap A.G-4
    b. Purchased Scrap A.G-5
    c. Ferrous Scrap Grades A.G-7
    d. Nonferrous Scrap Grades A.G-14

4. MANAGEMENT PRACTICES A.G-18
    a. Land Disposal A.G-18
    b. Combustion (and Other Processing Methods) A.G-20
    c. Recycling A.G-22

REFERENCES A.G-42

APPENDIX A
MAJOR WASTE STREAM COMPONENTS

G. METAL AND WHITE GOODS

1. INTRODUCTION

Discarded metals and white goods in municipal solid waste (MSW) consist of some obvious materials such as beverage containers, scrap metals, and appliances. Not so evident are other metals such as the silver in photographic film and precious metals in electronic components. This appendix examines the types of metal-bearing materials in the waste stream and the existing methods for disposing of or processing those materials. For a more detailed look at batteries and automobiles, the reader is referred to Appendix A.F and Appendix B.C, respectively.

2. WASTE COMPOSITION AND QUANTITIES

As mentioned above, some metal-bearing wastes are inconspicuous components of multimaterial products. Most waste sampling surveys do not address the composition percentages of the multimaterial products or verify the composition among manufacturers of products. Therefore, it is difficult to assess, with accuracy, the quantity of each metal in the waste stream. As a result, most sampling surveys break down wastes into general categories.

For metallic wastes, the general categories are ferrous metals, aluminum, and other nonferrous metals. A 1986 survey places gross discards of all metals at 13.7 million tons per year or 8.7 percent of all waste.[1] These discards are comprised of the metals shown in Table A.G-1.

TABLE A.G-1
METAL DISCARDS

	Gross Discards (million tons)	Recovered Materials (million tons)	Net Discards (million tons)
Ferrous metals	11.0	0.4	10.6
Aluminum	2.4	0.6	1.7
Other Nonferrous	0.3	0.1	0.3

From these general categories, metals can be separated as shown in Table A.G.-2.[2]

TABLE A.G-2
SEPARATION OF METALS

	1986 million tons	Discards %
Durable Goods:		
Appliances	2.6	1.8
Containers and Packaging		
Steel beer and soft drink cans	0.1	0.1
Steel food and other cans	2.4	1.7
Other steel packaging	0.2	0.1
Aluminum beer and soft drink cans	0.7	0.5
Aluminum foil and closures	0.3	0.2

Other categories that may contain metals under this classification method include miscellaneous durable goods (such as electronics, computers, jewelry, and automobiles) and miscellaneous nondurable goods (such as photographic film, leaded paint, dental fittings, and batteries). Together, miscellaneous durable and nondurable goods account for 8.5 percent of the waste stream, or 11.3 million tons annually. These quantities, however, can include plastics, glass, ceramics, wood, and other materials. A case in point is a television set that can include a wooden cabinet, metal fittings, glass tubes, rubber electrical cord, and metal wiring. When discarded, the set is classified as miscellaneous durable goods.

---

[1] Franklin Associates, Ltd. Characterization of Municipal Solid Waste in the United States, 1960 to 2000, Update 1988, Franklin Associates, Ltd., March 30, 1988.

[2] Franklin.

It is known that some undesirable materials may be present in some items that are processed for the recycling of metals. For example, polychlorinated biphenyls (PCBs) were previously utilized in the electrical components of large appliances and automobiles. There is currently some question as to the fate of PCBs in these items when they are processed for recycling. This PCB issue is indicative of the difficulties related to knowing what the many components of appliances, automobiles, and miscellaneous durable and non-durable goods consist of and how these components will be affected by various processing or disposal methods.

Determining the quality of metals in the waste stream becomes more complicated when the composition of each metallic material is examined. Other materials (such as plated metals and alloys) contain two or more separate metals in various combinations. The bimetal beverage can is a good example of two different metals combined into one metal item. Other notable items with more than one metal include tin-plated cans, galvanized steel, and alloys of iron and copper (such as stainless steel and brass).

Each metal is subject to fluctuations in generation and to subsequent disposal. Notable trends include a decreased use of lead (in piping, gasoline, and paints); increased use of aluminum; and increased use of special metals (such as platinum). As discards, steel cans from food and other uses are gradually decreasing from 2.4 million tons annually in 1987 to a projected 1.8 million tons in the year 2000. In contrast, discarded aluminum beverage cans will increase from 0.7 million tons in 1986 to 1 million tons in the year 2000. The two general categories of miscellaneous durable and nondurable goods, which can contain a variety of waste types, are forecast to increase from 11.3 million tons discarded in 1986 to 14.7 tons discarded in the year 2000.

3. GRADES AND TYPES OF SCRAP METAL

To the metal industry in general, scrap metal is both a usable material and a byproduct. Our modern industrial economy produces an enormous variety of metals. For each type of metal produced, a type of scrap metal could be described. It would be of little value to list each metal type available for sale. The most valuable scrap metal is made of metal with uniform and well-known properties. Since not all scrap metal can meet tight specifications, the metal is separated and prepared into lots that will give the scrap metal consumer the consistency of composition required for a given process.

The specifications for some metal types are very strict, and some reclamation processes are very intolerant of specific contaminants. In such cases, the amount and type of contamination of the materials used must be very limited. Other metal production processes are relatively tolerant of contamination and can use less-expensive scrap metal. The following paragraphs will characterize the various types of scrap metal recognized by the industry. First, some broad categories of scrap are discussed. Following that is a listing and description of scrap metal types organized by primary metal content.

a. Home Scrap

The consumers of scrap metal are, in general, smelters and foundries and chemical reclaimers that produce new metal from old. These manufacturing processes, like any other metal working process, produce scrap metal, which is classified as home scrap. It is also sometimes referred to as "revert," or "run-around," scrap because it is internally recovered and recycled into the plant process.

One of the basic constraints on the use of scrap metal for making new metal is a lack of knowledge of its composition. Home scrap is the preferred scrap for most operations because it tends to be homogeneous and relatively uncontaminated. Also, the material is on hand and does not need to be purchased. In fact, the Institute of Scrap Iron and Steel (ISIS) estimated that 51 percent of all iron and steel scrap used falls into this category.[3]

For some facilities, such as those using the basic oxygen furnace (BOF) smelting technology, home scrap is sufficient to provide all the scrap required for efficient operation. More recently, BOF's have been able to use much larger proportions of scrap as feedstock, resulting in more "outside" scrap purchases. The electric-arc furnace typically is able to supply only 20 percent of its scrap requirements internally.[4]

b. Purchased Scrap

Purchased scrap metal is any scrap that must be purchased by the metal consumer form outside its own plant. This is the material upon which scrap metal processors and brokers have built their businesses. Business is basically the preparation of relatively uniform lots of metal, which will give scrap metal consumers the control they need over their process.

The industry has defined over 260 standard grades of scrap to facilitate sales between processors and consumers. The specifications for these standard grades are intended to provide information about the metal without the need for inspection or analysis. Scrap is also sold without reference to a particular grade by mutual agreement between buyer and seller. This sale occurs when a usable quantity of scrap is available that does not fall neatly into a particular grade. Purchase scrap can be divided into the two categories described below.

---

[3] Phoenix Quarterly, Winter 1984.

[4] Pope-Reid Associates, Inc. The Scrap Metal Recycling Industry: Report to the U.S. EPA, April 1986.

- Prompt Scrap: Prompt, new, or industrial scrap is a byproduct of the metal-working industry. It includes shavings and turnings left after metal is drilled or machined. It also includes sheet metal from which can lids or other shapes have been punched. In general, any company that uses metal to manufacture a product also produces scrap. The difference between this category and home scrap is that this material must be sold to a scrap metal consumer for reuse. The scrap processor or broker collects this material, processes it if necessary, and delivers it to the consumer. The material is often new metal with relatively little corrosion or other contamination and is, therefore, considered high-quality scrap. Exceptions from machine shops would include shavings and turnings that are coated with lubricating oil, or with bits and pieces of metal swept up with other debris off a factory floor. According to ISIS, 18 percent of all ferrous scrap reclaimed falls into the "prompt" category.[5]

- Obsolete Scrap: Also called "old" scrap, obsolete scrap encompasses the most visible sector of the scrap metal industry. Any metal product, once it is no longer serviceable, can become obsolete scrap. It is important to differentiate between products that can be used again and those whose only value is in their metal content. Junked automobiles, for instance, often find their way to an auto dismantler who removes serviceable parts before selling the hulk to a scrap processor. Only the hulk, which is destined to be shredded and remelted, is considered obsolete scrap metal. The result will become used auto parts.

---

[5] Phoenix.

Because removing contaminants and separating the metal into usable lots requires more processing, obsolete scrap makes up the bulk of the stockpiles of metal found in scrap yards. Although it is generally true that obsolete scrap is the last to be purchased during periods of low demand, there are highly valued grades composed largely of obsolete scrap. The most prevalent example would be used structural steel from demolished buildings and bridges, which are a large source of No. 1 and No. 2 heavy melting steel. Shredded scrap, railroad scrap, and used aluminum beverage containers are also valuable types of obsolete scrap. ISIS estimates that 31 percent of all ferrous scrap reclaimed falls into this category.[6] As mentioned above, however, obsolete scrap constitutes a large portion of the inventory of scrap on hand at any given time.

c. Ferrous Scrap Grades

By far the most common metal used by modern industry is iron. Consequently, ferrous scrap forms the largest component of scrap metal. There are well over 100 recognized grades of ferrous scrap. The following is an excerpt from the ISIS Handbook that gives some general requirements for all grades of ferrous scrap.

---

[6] Phoenix.

GENERAL a. Cleanness. All grades shall be free of dirt, nonferrous metals, or foreign material of any kind, and excessive rust and corrosion. However, the terms "free of dirt, nonferrous metals, or foreign material of any kind" are not intended to preclude the accidental inclusion of negligible amounts where it can be shown that this amount is unavoidable in the customary preparation and handling of the particular grade involved.

b. Off-grade material. The inclusion in a shipment of a particular grade of iron and steel scrap of a negligible amount of metallic material which exceeds to a major extent the applicable requirements as to quality or kind of material shall not change the classification of the shipment, provided it can be shown that the inclusion of such off-grade material is unavoidable in the customary preparation and handling of the grade involved.

c. Residual alloys. Wherever the term "free of alloys" is used in the classifications given herein, it shall mean that any alloys contained in the steel are residual and have not be added for the purpose of making an alloy steel. Steel scrap shall be considered free of alloys when the residual allowing elements do not exceed the following percentages:

	Percent
Nickel.............................	0.45
Chromium...........................	0.20
Molybdenum.........................	0.10
Manganese..........................	1.65

The combined residuals other than manganese shall not exceed a total of 0.60 percent.[7]

---

[7] Institute of Scrap Iron and Steel, Inc. (ISIS). Institute of Scrap Iron and Steel, Inc., Handbook, Including Specifications for Iron and Steel Scrap, 1979 (fourth printing April,1985), p.5.

d. Deviations. Any deviations from the general classifications or iron and steel scrap may be consummated by mutual agreement between buyer and seller.[a]

As can be seen from the above ISIS specification, all grades of ferrous scrap can be expected to contain a certain amount of contamination and alloy metal content.

ISIS has classified 71 grades of ferrous scrap into five groupings according to the most likely purchaser of the material. Table A.G-3 summarizes the types of material to be found in each of these five basic groups.

TABLE A.G-3

FIVE GROUPS OF FERROUS SCRAP

I. Basic Open Hearth, Basic Oxygen, Electric Furnace, and Blast Furnace Grades

A. No. 1 Heavy Melting Steel

No. 1 heavy melting steel is composed of wrought iron and/or steel over 1/4 inch thick and prepared in a manner to ensure compact charging. Galvanized and other coated steel is not allowed. The specifications for the three grades of No. 1 steel differ only in the allowable size of the individual steel pieces.

B. No. 2 Heavy Melting Steel

There are four grades of No. 2 heavy melting steel specified. Both black and galvanized steel is allowed, as well as wrought iron. No. 2 steel is less valuable than No. 1. It is, in general, material not suitable as No. 1 heavy melting steel.

---

[a] ISIS.

TABLE A.G-3
(continued)

C. Busheling

This includes clean steel scrap with size limitations. It cannot include metal coated, lined, or enameled metal sheet steel with more than 0.5 percent silicon, or old auto body and fender stock. It can include clippings and stampings from sheet steel. The two grades are almost entirely composed of industrial scrap. The name derives from scrap placed in baskets in the last century.

D. Bundles

No. 1 bundles are to be black steel. Chemically detinned material is also allowed.

No. 2 bundles can include old steel and galvanized steel. Although less stringent than the specifications for No. 1 bundles, metal coated and enameled material is still, in general, not allowed.

No. 3 bundles are to include coated scrap not appropriate for No. 2 bundles.

Two other grades have been established for incinerated tin can scrap and terne plate. The term, "factory bundles," normally refers to No. 1 bundles.

E. Bundled Steel

Bundled steel is not the same as steel bundles. The difference is that bundled steel scrap is to be at least 1/8 inch thick. There are two grades. One is meant to be steel scrap from auto hulks, and the other must be free of all metal coated materials.

F. Shredded Steel Scrap

The most common source of shredded scrap is old automobile hulks. The specifications for two otherwise identical grades call for an average density of 50 and 70 pounds per cubic foot, respectively. The specifications also call for

TABLE A.G-3
(Continued)

magnetic separation, which will leave a fairly large quantity of nonmetallic and nonferrous material for disposal at the shredder site.

Household appliances and other miscellaneous steel are also occasionally run through a shredder. There are two grades of shredded scrap that do not include auto hulks. One consists of new nonalloyed steel sheet. The other is for shredded tin cans.

G. Turning and Borings

There are several grades of this scrap metal from machining operations. This is industrial scrap resulting from the use of drills and lathes. It is often heavily contaminated with lubricating oil and is one of the lowest grades new scrap.

H. Mill Scale

This consists of ferro-magnetic oxide formed on the surface of steel articles during heating and working.

II. Electric Furnace Casting and Foundry Grades

The limitations of ferrous scrap to be used in foundry and casting operations are more stringent than those for smelting operations. Less nonferrous metal, either alloyed or as free metal, is tolerated. Phosphorous, sulphur, and silicon content is also more restricted in most grades.

A. Crop, plate, cast, ingot, and structural steel

There are ten grades defined for this relatively thick and heavy material. There are restrictions as to minimum thickness and maximum width and length of the individual pieces. As mentioned above, phosphorous, sulphur, and silicon content is generally restricted.

B. Silicon busheling, clippings, and bundles

These grades allow silicon content of up to 5 percent. The requirements for physical size and chemical content are otherwise similar to

TABLE A.G-3
(Continued)

comparable grades that do not allow over 0.5 percent silicon.

C. Turnings

Three grades of turnings are defined, which specifically mention limitations on alloys, iron borings, excessive oil, and phosphorous and sulfur. Another grade, heavy turnings, specifically excludes light material generated by machine shops.

D. Foundry Steel

Steel for these grades must be at least 1/8 inch thick, cut to relatively small dimensions, and free of either cast or malleable iron.

E. Hard Steel

This grade is meant for automotive steel consisting of rear ends, crank shafts, drive shafts, axles, springs, and gears. It is not to include either small shoveling steel or pieces too large for foundry use.

III. Specially Processed Grades of Ferrous Scrap

These are grades that must, in general, be processed with a particular consumer in mind. Individual specifications must be agreed upon between the buyer and seller.

IV. Cast Iron Grades

There are five grades of cast iron that vary primarily by allowable size. A sixth grade has been established for burnt iron such as stove parts and grate bars, which were once much more common than they are today. There are also grades calling for "broken cast," which means the material must be broken down under a drop to a specified size.

A. Automobile Engine Blocks

Cast iron engine blocks are sold either broken to pieces under 150 pounds or left intact with steel and nonferrous fittings still attached.

TABLE A.G-3
(Continued)

B. Malleable Iron

This includes wrought iron free of steel and cast iron primarily from automobile and railroad cars.

V. Special Boring Grades

There are five grades of cast and malleable iron borings defined. These grades are made up of new scrap, are to be free of steel turnings, and are to be restricted as to oil and water content. Two of these grades are made into briquettes and have minimum densities defined.

Besides the five groupings discussed above, there is an entire class of ferrous scrap called "Railroad Ferrous Scrap." The specifications for these grades come from the Association of American Railroads.

The railroad industry is estimated to produce around 3 million tones of ferrous scrap per year.[9] Because this scrap is very consistent in its metallurgical content, it is highly regarded by some scrap metal consumers. The larger railroads sell their scrap at monthly auctions; this scrap is, therefore, used to establish the price of many types of scrap. Over 40 grades of railroad ferrous scrap have been defined by the Association of American Railroads. These grades are defined primarily by the railroad parts from which they are derived. The following lists the categories of material for which specifications have been written:

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[9] Phoenix.

Axles
Connectors (includes spikes, bolts, nuts, washers, etc.)
Cast Steel
Cast Iron
Couplers or Knucklers
Steel Frogs and Switches
Malleable Parts and Castings
Melting Steel
Rail Steel
Sheet Scrap
Tool Steel
Uncut Structural Steel and Wrought Iron
Locomotive Tire
Turnings
Wheel
Destroyed Steel Cars, Car Sides, Boxcar Roofs

d. Nonferrous Scrap Grades

The National Association of Recycling Industries (NARI) provides specifications for nonferrous scrap metal. The various grades are identified by code words as well as number designations and descriptive titles.

TABLE A.G-4
GRADES OF NONFERROUS SCRAP

1. Copper and Copper Alloys

There are nine grades of unalloyed copper scrap defined as well as grades named "Copper Bearing Scrap" and Insulated Copper Wire Scrap." There are generally limitations on minimum copper content as measured by electrolytic analysis. Restricted material includes burnt copper insulation, oil, brass, bronze, and other metals. Copper bearing scrap is to be "Free of

TABLE A.G-4
(continued)

insulted wires, copper chlorides, unprepared tangled material, large motors, pyrophoric material, asbestos brake linings, furnace bottoms, high lead materials, graphite crucibles, and noxious and explosive materials."

Brasses and bronzes are common alloys of copper, zinc, tin, and occasionally other metals such as lead. The composition of these alloys varies according to the intended use of the material. More than 25 grades of scrap brass and bronze material are defined by the scrap metal industry. For some grades, it is recommended that the material be analyzed before it is sold. Other grades have minimum copper content specified, a range of zinc or tin to be allowed, and a maximum allowable lead or iron content.

Some terms that are associated with these alloys and that might be useful include

- Red and yellow brass: Brass with higher copper content is called red brass (85-15); lower copper content material is called yellow brass (70-30).
- Babbit: This material is used to line bearings, usually, and consists of an alloy of copper, tin, and antimony.
- Nickel-Silver: This is an alloy of copper, zinc, and nickel.

2. Lead and Tin

The scrap metal industry has defined more than a dozen grades of primarily lead or tin scrap. Soft scrap lead consists of relatively clear, pure lead. Other lead grades include battery plates, drained batteries, lead-bearing brass, and lead-covered copper cable. Block tin is to be at least 98 percent pure tin. Other tin grades have been defined for babbitt liner material and pewter, which is usually an alloy of tin and lead.

3. Zinc

One of the largest uses of zinc is in galvanized steel. This is a process in which steel is electrolytically coated with zinc. Waste zinc from the bath in which

TABLE A.G-4
(continued)

the steel is coated forms two different grades of zinc depending on the galvanizing profess from which it derives. Other grades are defined for zinc-based die castings and zinc sheets and stampings. Specifications for these grades limit the amount of "unmeltables" (such as iron) that will be allowed.

4. Aluminum

Various alloys of aluminum are available for sale. Like ferrous metals, these alloys have been given an alloy containing manganese and is the most common ally used in aluminum beverage containers. Other elements commonly alloyed with aluminum are copper, silicon, magnesium, and zinc.

NARI has defined a total of 33 grades of aluminum scrape including four grades of new and old aluminum can stock, clippings, foil, turnings, wire and cable, grindings, castings, and extrusions. In general, aluminum scrap segregated into a single alloy is more valuable than mixed aluminum. Some grades call for segregated aluminum, some for mixed. Old aluminum from specific products is called for in some grades of aluminum scrap. Examples of the type of material called for in these grades would be painted house sidings, radiators, pistons, foil, auto castings, and airplane sheet aluminum and castings. There is also one grade of aluminum defined on the basis of a recovery procedure. Sweated aluminum is aluminum that has been heated with some other attached metal (such as iron) with a higher melting temperature than aluminum. By heating the metal to a temperature at which aluminum but not iron melts, the molten aluminum can be separated and collected.

5. Magnesium

The industry defines five grades of magnesium scrap. There are limitations on brass, copper, aluminum, and zinc, as well as nonmetal contaminants such as dirt and oil.

6. Nickel

New nickel, old nickel, and miscellaneous types of nickel form the three grades of nickel scrap that have been defined. New and old nickel call for 99 percent

TABLE A.G-4
(continued)

and 98 percent nickel content, respectively.

7. Cupro-nickel and Monel

Cupro-nickel and Monel are both alloys of copper and nickel. The difference is in the predominant metal. Cupro-nickel is primarily copper. Monel, on the other hand, is primarily nickel. The types of monel scrap that are defined will vary in nickel content and in the other metals of the alloy mix. Ten grades of cupro-nickel and monel have been defined. Most require segregation into a single type of cupro-nickel or monel alloy.

8. Stainless Steel

The term "stainless steel" refers to a group of alloys composed primarily of iron, chromium, and nickel. Chromium content may vary from about 13 to 27 percent. Many, but not all, stainless steels contain 8 to 10 percent nickel. Two grades have been defined for the most common type of stainless steel scrap. These grades require a minimum 16 percent chrome and 7 percent nickel. Molybdenum, copper, phosphorous, and sulfur contents are restricted to specific maximum levels.

Another grade is defined for mixed grades of stainless steel and is restricted to a maximum 0.5 percent copper. Straight chrome stainless, which does not include nickel, has two grades defined for it, depending on chromium content. These last two grades are restricted to a maximum of 0.5 percent.

9. Ferro-Nickel Alloys

This grade is for alloys of nickel and iron only. Copper is restricted to a maximum of 0.5 percent and nickel to a minimum of 20 percent.

TABLE A.G-4
(continued)

10. Mixed Nonferrous Metals from Resource Recovery Facilities

This grade is composed of mixed nonferrous metals. Iron and nonmetallic substances are restricted to 3 percent each. So that separation does not become difficult, material is to be loaded loosely and not compressed or baled.

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4. MANAGEMENT PRACTICES

At first glance, management of metals seems deceptively simple. Most are landfilled with recycling accounting for increasing levels of management. Beyond this elementary view, it is evident that each metal is recovered and recycled in distinctly different ways. When discarded, however, most metals and metal-bearing products are handled similarly. To illustrate these practices, this section will be divided according to land disposal methods, combustion (or other processing methods), and recycling methods.

a. Land Disposal

The vast number of landfills in the country and the relatively convenient, low-cost aspects for disposing of wastes in landfills make land disposal the most used management practice for metals.

There appear to be two primary methods of handling metals at landfills. One is the burial of metal products along with other wastes entering the landfill. The second is hand separation at the landfill of white goods and other large metal items for eventual recycling. Although no data substantiate it, we suspect that smaller landfills and local dumps conduct more separation activities because incoming waste volumes are often low and more time is available for hand sorting. Larger landfills with heavy daily volumes do not often have the opportunity of sorting before daily cover placement. We also suspect that larger facilities cannot efficiently sort loads of waste to recover metals. Some metals are frequently disposed of in construction debris landfills or mono-fills where fewer environmental controls are necessary. Although sanitary landfills for mixed waste often have sophisticated leachate control systems, there is the potential for wastes to interact and form hazardous constituents (such as acids from batteries or household wastes reacting with lead).

The characteristics of metals, once placed in a landfill, vary according to type and composition. Scrap metal samples, (such as brasses, lead shot, stainless steel, and automobile radiators) that were tested for extraction procedure (EP) toxicity indicated that lead was the only parameter to exhibit concentrations above the EP toxicity limits for all samples except red brass and stainless steel.[10] Lead is present in many products such as paint, gasoline additives, solder, batteries, ammunition, printing type, piping, electrical components, and various alloys. When landfilled, lead seems to deteriorate fairly slowly except in lead-acid batteries where the acid can corrode the lead and release lead into the landfill. The use of lead in batteries is growing (see Appendix A). The acid in batteries may also cause the leaching of cadmium, chromium, and other nonmetallic toxic constituents.[11]

Most metals resist deterioration in landfills. Stainless steel, zinc, nickel, tin, magnesium, and other nonferrous metals and their alloys appear to present little or no hazard to the environment and public health when landfilled. The reason is twofold: they are valuable enough to ensure high recovery rates (thus, landfill volumes are fairly low), and most are considered non-toxic.

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[10] Pope-Reid.

[11] Pope-Reid.

Land disposal of combustion ash and sludges is also known to contain various concentrations of metals that could have an impact on surface water and ground water through leachate generation. These two waste management issues are examined in detail in Appendix B.A and B.D, respectively.

b. Combustion (and Other Processing Methods)

Solid waste combustion facilities and other processing facilities (such as composting) fall into two categories as far as metals handling is concerned. One is the processing of unsorted solid waste (such as in a mass-burn incinerator), and the second is processing that presorts waste (such as refuse-derived fuel (RDF) and compost facilities).

Nonsorting facilities may still provide space for large metal items (such as white goods) but, generally, the metals in the solid waste that is deposited at the facility are incinerated. Other than being low in energy value, metals contribute to detrimental air emissions when combusted. Potential emissions include oxides of cadmium, mercury, lead, and chromium, which can be caused in particular by coatings and paints on materials. Various pollution control devices can limit or even virtually eliminate the dispersal of many contaminants. Lead and mercury are more difficult to control, however.

The incineration of metals causes slagging in which partial melting occurs along with some volatilization. Table A.G-5 identifies common metals and alloys with a range of melting points.[12]

TABLE A.G-5
MELTING POINTS

Metal/Alloy	Melting Range Degrees Fahrenheit
Aluminum	1065-1215
Copper	1980
Brasses	1650-1880
Carbon Steel	2760
Gray Cast Iron	2100-2200
Stainless Steels	2500-2790
Nickel Alloys	2370-2635
Titanium and Alloys	2920-3100
Lead	618
Zinc	787
Tin	450

Melting points are important to consider because slagging is a frequent problem in combustion facilities. Slag and unburned metals are eventually disposed of as ash (further described in Appendix B.A).

Combustion or other processing facilities with presorting of waste can still have operational problems because of metals, but there is more control over the incoming waste, which does not minimize those problems. One of the most basic sorting techniques is providing a magnet to pull out ferrous materials. Nonferrous materials can be removed to varying degrees by air classification, screening, hand sorting, or water sorting. Sorted materials are marketed if the conditions and quantities warrant the expense. Unsorted metals cause the same or similar impacts in RDF combustion facilities as they cause in mass-burn facilities. The major difference arises when waste containing metals is shredded or ground to reduce its size in the RDF (or composting) process. Shredders or grinders can be damaged by large pieces of metal. Operational controls and inspection of incoming waste are required to prevent such occurrences.

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[12] Green, Don W. Perry's Chemical Engineering Handbook, 6th ed., 1984.

c. Recycling

The scrap metal recycling industry in the 1980's is a mature and sophisticated industry. Scrap metals account for large percentages of the total material used in the manufacture of new metal products by American industry: for example, about 55 percent of the copper, 50 percent of the lead, 40 percent of the stainless steel, 40 percent of the gold, 29 percent of the aluminum, 28 percent of the silver, 26 percent of the iron and steel, and 15 percent of the zinc.[13]

In the past two decades, the flow of scrap metal to consumer plants in the Northeast has shifted to newer facilities in the Southwest and West. ("Consumer" is the term used by the industry to describe the plants that are users of scrap metal). For example, the closing of copper scrap refineries in the Northeast by Asarco, Phelps Dodge, And Anaconda had a sharp impact on the movement of copper scrap in that area. Many of these consumer plants are now located in the Southwest and West.

(1) Types of Businesses as Defined by the Industry

The scrap metal recycling industry consists primarily of different businesses: scrap collectors and scrap processors.

- Scrap collectors collect scrap materials (e.g., paper, metal, user appliances) and sell the material to other businesses, in some cases to scrap processors. An auto dismantler is a very predominant class of collectors that deal in parts which are removed from wrecked or obsolete cars. After the saleable parts have been removed, the remaining hulk is sold by weight to a scrap processing plant

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[13] National Association of Recycling Industries, Recycled Metals in the 1980's, 1982.

- A scrap processor uses machinery and equipment for processing iron, steel, or nonferrous metallic scrap into prepared grades.

In addition to those two businesses, foundries, smelters, steel mills, mini-mills, blast furnaces, and refineries typically will consume or reclaim scrap metal; they do not, however, necessarily process scrap metal. These business types are included because, as consumers, they handle scrap metal.

Three different types of processes consume or reclaim scrap metal. The first method, typically used in foundries, is a process in which the material is melted and mixed with other metals to produce a metal of known composition. A second process, used in steel mills, employs a smelting furnace to purify metal. The third process, which is used to purify certain nonferrous metals, involves recovering scrap metal from chemical solution of by electrolytic precipitation. The major consumers of metallic scrap are steel mills, foundries, smelters, and refiners.

(2) Industry Characteristics

It is difficult to provide current detailed information that describes the total industry for scrap metal recycling in the United States. The scrap metal recycling industry is not categorized under one standard industrial classification (SIC) code. Businesses in the industry are categorized under SIC Codes

3341 (Secondary Nonferrous Metals), 3312 (Blast Furnaces and Steel Mills), and 5093 (Scrap and Waste Materials).

However, using 1982 Census data[14] we estimate that there are approximately 7,127 establishments handling scrap metal in the United States.[15] Of those establishments, there are approximately:

- 458 smelters
- 499 blast furnaces and steel mills
- 6,170 scrap and waste materials businesses

This appendix focus primarily on the last group of businesses. The others are included as users of scrap metal and as waste processors in a small number of plants. In general, the vast majority of all scrap and waste material businesses or establishments employ fewer than 50 people. Most of the establishments have annual sales of less that $5 million. The majority of establishments operate only one plant. Corporations are the most common legal form or organization. Geographically, the industry is concentrated in the North Central and Northeast States.

(a) Secondary Smelters and Refiners of Nonferrous Metals (SIC 3341)

SIC Code 3341 represents secondary nonferrous metals establishments that are engaged primarily in recovering nonferrous metals and alloys from dross, which is a residue from the smelting process, and from prompt and obsolete scrap. The industry also includes establishments engaged in the recovery and alloying of precious metals, and in the recovery of tin through secondary smelting and refining.

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[14] U.S. Department of Commerce. 1982 Census of Manufacturers.

[15] The U.S. Census Bureau updates these figures every 5 years with a reporting log time of 1 to 2 years. The next reports are scheduled for 1987 but most likely will be published in 1989. It is possible that the number of these establishments has decreased because of economic conditions, mergers, acquisitions, and so forth.

In 1982, 458 of these establishments operated in the United States and employed 19,200 people. This portion of the industry accounts for approximately 6 percent of the total industry represented by SIC 3312, 3341, and 5093. Table A.G-6 presents the number of establishments at different sizes for smelters and refiners. Approximately 24 percent of the companies had 1 to 4 employees, while 16 percent had between 5 and 9 employees. In other words, 40 percent of these businesses had fewer than 10 employees. 75 percent of the establishments had 49 employees or fewer.

TABLE A.G-6
NUMBER OF ESTABLISHMENTS BY SIZE OF FIRM--SIC CODE 3341
SECONDARY SMELTING AND REFINING OF NONFERROUS METALS

Employment Size of Establishment	No. of Establishments
1 to 4 Employees	111
5 to 9 Employees	74
10 to 19 Employees	61
20 to 49 Employees	96
50 to 99 Employees	59
100 to 249 Employees	48
250 to 499 Employees	8
1,000 to 2,499 Employees	1

Source: U.S. Department of Commerce. 1982 Census of Manufacturers.

(b) Blast Furnaces (Including Coke Ovens), Steel Works, and Rolling Mills (SIC 3312)

SIC 3312 includes establishments engaged primarily in the manufacture of steel sheet, strip, bars, and wire. Also included are businesses that manufacture pig iron, coke, and other blast furnace products. They are also primary users of scrap metal and engage in some processing.

In 1982, 499 of these establishments operated in the United States and employed 297,500 people. This segment of the industry accounts for approximately 7 percent of the total represented by SIC 3312, 3341, and 5093.

(c) Businesses Dealing in Scrap and Waste Materials (SIC 5093)

Number of Establishments. SIC 5093 represents the category "Scrap and Waste Materials," which includes iron and steel scrap processors, dealers, and waste and secondary materials dealers. Table A.G-7 illustrates the geographic distribution throughout the country of scrap and waste materials establishments.

TABLE A.G-7
NUMBER OF ESTABLISHMENTS DEALING IN SCRAP AND WASTE MATERIALS THROUGHOUT THE UNITED STATES--SIC CODE 5093

Geographic Area	No. of Firms
Alabama	138
Alaska	-
Arizona	101
Arkansas	70
California	721
Colorado	88
Connecticut	129
Delaware	17
District of Columbia	10
Florida	337
Georgia	196
Hawaii	17
Idaho	17
Illinois	499
Indiana	192

TABLE A.G-7
(continued)

Geographic Area	No. of Firms
Iowa	99
Kansas	74
Kentucky	76Louisiana 99
Maine	41
Maryland	95
Massachusetts	252
Michigan	312
Minnesota	114
Mississippi	52
Missouri	174
Montana	18
Nebraska	40
Nevada	15
New Hampshire	35
New Jersey	367
New Mexico	27
New York	792
North Carolina	212
North Dakota	17
Ohio	431
Oklahoma	98
Oregon	78
Pennsylvania	529
Rhode Island	53
South Carolina	100
South Dakota	23
Tennessee	139
Texas	482
Utah	42
Vermont	11
Virginia	108
Washington	125
West Virginia	50
Wisconsin	180
Wyoming	10
United States	7,900

Source: U.S. Department of Commerce. 1982 Census of Wholesale Trade.

- In 1977, 7,428 establishments were operating throughout the United States.
- Of those, 7,219 were classified as merchant wholesalers while 209 were considered agents, brokers, or commission merchants.
- Of the 7,219 establishments, 3,830 composed the ferrous metal industry (processors and dealers) and 3,389 composed waste and secondary materials dealers.
- Of the 3,830 ferrous metals processors and dealers, 2,148 ferrous processors used "power-processing" equipment, and 1,682 ferrous dealers did not use power-processing equipment.
- Some waste and secondary materials dealers handle rags, textiles, cloth, and paper. Of the 3,389 dealers, we estimate that 69 percent of the establishments (2,340) handle nonferrous scrap metals.
- A conservative estimate is approximately 6,170 establishments in SIC 5093 that handle scrap metal.

(3) Size of Establishments

The following characteristics provide different measures of the size of the industry in SIC 5093:

- Number of employees b type of operation.
- Annual sales by type of operation.
- The number of single or multi-unit operations.

Table A.G-8 presents the number of establishments at different sizes for all types of operations, including merchant wholesalers, agents, brokers, and commission merchants. These terms are defined as follows:

- Merchant Wholesalers: Businesses that engage in wholesale trade of goods
- Agent: Businesses that represent the interests of another business
- Broker: Businesses that engage in buying or selling materials, with little or no handling of the materials
- Commission Merchants: Businesses that engage in the purchase or sale of goods or services for a percentage of the transaction as income

A total of 83,735 people were employed by businesses in this segment (SIC 5093) of the industry. Merchant wholesalers employed 82,414 people while agents, brokers, and commission merchants employed 1,321. Of the 82,414 workers, 37,346 were employed by waste and secondary materials dealers while 45,068 people were employed by iron and steel scrap processors and dealers. The ferrous metals processors and dealers can be further divided into the following categories: 11,772 individuals employe by dealers and 33,396 workers employed by processors.

(4) Scrap Metal Consumers

Scrap metal is, in general, consumed b being melted and reshaped into useful new products. Industries that use the new products will buy the new metal products in a number of forms including sheets, plates, bars, ingots, or castings. This metal has specific, well-defined characteristics.

TABLE A.G-8

NUMBER OF ESTABLISHMENTS DEALING IN SCRAP AND WASTE MATERIALS BY SIZE AND TYPE OF FIRM--SIC CODE 5093

Employment Size of Establishment	All Types of Operations	Merchant Wholesalers	Agents, Brokers, Commission Merchants
Establishments Operated the Entire Year	6,798	6,612	186
No Employee[16]	94	91	3
1 Employee	994	962	32
2 Employees	797	770	27
3 or 4 Employees	1,119	1,075	44
5 or 6 Employees	775	753	22
7 to 9 Employees	759	734	25
10 to 14 Employees	747	731	16
15 to 19 Employees	796	784	12
50 to 99 Employees	206	204	2
100 or more Employees	65	65	--
Establishments Not Operated the Entire Year	630	607	23
	7,428	7,219	209

Source: U.S. Department of Commerce, 1982 Census of Wholesale Trade.

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[16] "No Employee" is assumed to refer to an owner/operator who has no additional employees.

"New" metal is the consumer's product and scrap metal is discarded consumer products that become raw materials for the industry. There are three different industrial processes by which scrap metal can be made into new materials. The first, used in foundries, is a process by which the scrap metal is melted and mixed with other metal(s) to produce a metal of known composition. Another process, used in steel mills, uses a smelting furnace to purify the scrap metal in the same manner as one would purify metal-bearing ore. The third process, used to purify nonferrous metals such as copper and aluminum, involves the recovery of the scrap metal(s) from solution of chemical or electrolytic precipitation. The following text describes the reclaiming processes in more detail, in particular, the scrap metal material specifications and handling problems.

o Foundries and Similar Processes

The melting and pouring of metal into useful or convenient shapes is an important aspect of the metal industry. Any cast metal object is the product of a foundry. A casting is made by pouring molten metal (such as iron, aluminum, or brass) into a mold that defines the shape of the cooled and hardened object. The furnace or oven used to accomplish the melting for these processes is rather simple compared with a smelting furnace. The function of this equipment is to efficiently melt the metal. No purification of the metal is attempted. The composition of metal in the melt must be the same as the required composition of the casting to be sold. Because of this extremely limited tolerance for contaminants, the foundry is a consumer of high-grade scrap metal of uniform and well-known composition. Therefore, foundries are consumers of only a rather modest share of the total amount of scrap metal available.

- Smelters

  Smelters are used to separate metal from other constituents or impurities. To make purification possible, the furnaces used in this process are designed to take advantage of the properties of the metal. By careful control of temperature and by use of fluxing agents and reducing agents, a pure metal can be derived from a mixture of materials heated together. Pig iron, for instance, is the product of a blast furnace, a type of smelting operation. Steel is produced by smelters that take pig iron and further reduce the carbon content plus alloy the iron with the remaining carbon and any other additives desired. Carbon steel is the most common metal in use today. Some steel-making processes (such as the open-hearth furnace or the basic oxygen process) use some scrap steel as well as pig iron to produce new steel efficiently. The electric arc furnace, which has become more common recently, uses scrap steel exclusively,

  In the ferrous scrap market, which is by far the largest segment of the scrap metal industry, smelters are the primary consumers. They are able to use substantial quantities of scrap steel and, depending on their new metal products, may be able to use relatively contaminated material. The predominance of smelters as consumers of ferrous scrap is not duplicated in the nonferrous markets, because other purification techniques may be available.

- Chemical and Electrolytic Precipitation

  The use of chemical and electrolytic precipitation as a means of melting and purifying is found almost exclusively in the nonferrous segment of the industry. As an example, copper is commonly reclaimed by electrolytic means.

Electric current is run through a copper-bearing solution, which is made by dissolving copper with an appropriate solvent. Electrodes suspended in the bath become plated with copper. The copper plate is then melted. This process can be repeated using a more pure copper solution and can result in a virtually pure copper product.

The basic element that differentiates this process from the foundries and smelters described above is that the scrap metal is dissolved or melted chemically rather than by thermal means. The caustic or acid used and the means of purification may vary considerably depending on the metal to be recovered.

(5) Scrap Metal Marketing

It is considered a truism in the scrap metal industry that the scrap market is buyer controlled. There is, for all practical purposes, a sufficient quantity of scrap available to meet any demand if the price offered rises sufficiently to justify its recovery. On the other hand, the capacity of scrap metal consumers to use scrap is decidedly limited and will not respond to decreases in scrap prices. In other words, a business with scrap metal to sell cannot create demand by reducing the price. A business with a need to purchase scrap metal can, however, increase its supply by increasing the price it will pay. Hence, the well-known saying in the business is, "Scrap is bought, not sold."

As in any other industry, the cost of inventory maintenance must also be considered by those dealing in scrap metal. Since metal in a warehouse or scrap yard does not earn interest, a business with money invested in idle scrap inventory must consider the interest not earned as an expense. Because of the assumed availability of scrap for purchase and the cost of inventory maintenance, the well-managed scrap business will attempt to maintain only enough inventory to supply its current requirements.

These influences tend to produce a rather volatile market. At times when demand is becoming low, all those handling scrap--dealers, processors, consumers--are trying to reduce their inventory. This lower demand for scrap is essentially a direct result of fewer goods being purchased by the general public, which, in turn, is traditionally viewed as indicative of a downturn in the economy. Because fewer hard goods are being demanded and purchased, fewer are being manufactured. Thus, fewer materials--including scrap metal--are required by industry. Scrap metal consumers, therefore, drop the prices they are willing to pay, thus discouraging the flow of scrap to their facilities from dealers and processors.

Interestingly, this situation is the reverse of a classic supply and demand market. In the classic market, a drop in prices is typically followed by an increase in demand because of consumers wanting to take advantage of those lower prices. Lower prices in the scrap industry do not translate into increased demand, however. When scrap prices are low, no amount of clever marketing or advertising on the part of dealers can induce consumers to purchase more. The entity that controls the demand in this case also happens to control the prices it is willing to pay. The scrap industry as a whole, however, is ultimately at the mercy of the national, and even international, economy.

One of the basic characteristics of metal is that it can be recycled indefinitely. Since perhaps the beginning of civilization, metal objects have been used to make entirely different objects when the needs of society change. Thus, scrap metal is one of the earliest materials to have been traded. With the advent of the industrial revolution, the amount of metal available and in use has, of course, radically increased. In the

19th century, the open-hearth furnace, which requires scrap steel for efficient operation, began to produce steel in previously unheard of quantities. It is the enormous volume of metal exchanged today relative to previous centuries that primarily characterizes the modern scrap metal market. Over shorter time frames, of course, the scrap industry has grown and contracted. Rapid changes in demand, technology, and the economy as a whole have put pressure on the industry to adapt quickly to new conditions.

To accommodate this large and complex modern market, a number of types of businesses and organizations have evolved. The National Association of Recycling Industries (NARI) and the Industry of Scrap Iron and Steel, Inc., (ISIS) are trade organizations that look after various interests of their member organizations. One of their primary responsibilities is the establishment of specifications for grades of recyclable metal. These specifications facilitate the sale of scrap metal by making it possible for buyers and sellers to clearly communicate their metal needs.

The scrap metal broker provides the same kinds of services that any broker does. Full-time study and involvement in the market give the broker the advantage of up-to-date knowledge of price and availability. A broker can supply the consumer with a single contact through which a variety of scrap metal marketing needs can be met. Through long-term associations with his or her customers, a broker is able to provide guarantees of both quality and delivery in which the scrap metal consumer can have greater confidence.

Selling scrap metal overseas requires special knowledge and skills. First, the requirements of a foreign consumer may be different from those of a domestic consumer. There are also import and export regulations, import taxes, quotas, and marine insurance to consider. Foreign languages and the length of time between shipment and delivery can also pose special problems. the scrap metal exporter can be considered a broker who specializes in the overseas market.

Two principal futures exchanges deal in metals. COMEX (Commodities Exchange, Inc.), located in New York City, deals in aluminum, copper, silver, and gold. LME (London Metal Exchange) in London deals in copper, silver, tin, lead, zinc, and aluminum. A commodity futures contract is a standardized agreement to buy and receive, or to sell and deliver, a stated quantity and grade of a commodity at a definite future date. As the contract nears expiration, the imminent potential for delivery causes the price of the futures contract to approach the cash market value of the commodity. The futures market allows a business to protect itself from price fluctuations in the cash market by transferring risk to those who are willing to assume it.

Because of the volatility of the price of scrap metal, there are both the potential for quick and substantial profit and the danger of significant loss in the buying and selling of scrap. Speculators enter the market in the belief that they know the direction that scrap metal prices are going in the future. If they believe prices are going to rise, they purchase. If they believe prices will fall, they sell.

The opposite of speculation is hedging. This is the more common use of the futures exchange for businesses that must make a commitment to buy or sell metal months before the transfer actually occurs. To hedge, a position is taken so that the losses incurred because of a change in price will be offset by profits made in a separate trading action.

This position also results in the loss of profits that might have resulted from the opposite change in price. Significantly, most often the futures contracts do no result in an actual transfer of material. A trader of futures contracts can avoid any actual transfer by owning "offsetting" contracts. That is, if one is obligated to purchase a certain amount of scrap under one contract, one can also contract to sell the same amount at the same time and thereby remove one's responsibility to do either. This offsetting is significant because the standard futures contracts are limited in the specifications that may be called for and the location to which the material must be delivered.

Often a scrap consumer's requirements are such that it is necessary to take delivery only on material purchased on the cash market. The futures markets tend to reduce drastic short-term increases or decreases in price in favor of longer term price trends. Since the future contracts are an open auction of material, they are also important price-setting devices.

The other important price-setting mechanism is the auction of certain standard grades of scrap metal by large generators for cash sale. The bid prices for these standard materials are then used as reference prices for a wide variety of grades. As an example, "factory bundles" from the major automobile manufacturers are auctioned once a month. The price paid for many kinds of shredded and bundled scrap is then often set at a fixed percent or dollar value above or below that price. Long-term contracts are often written for the delivery of scrap with a certain set of specifications; the price to be paid is typically determined by one of these reference prices, many of which are published in American Metal Market and Iron Age.

The following discussion describes the marketing decisions that must be made by the various types of businesses in the scrap metal industry. The basic functional responsibility of the scrap metal industry described elsewhere can be involved in the purchase and/or sale of scrap metal. It should be noted that the corporate entities involved are often such that several of these functions are carried out by a single organization. If this is the case, there is no actual sale of material within the organization. There is, however, a transfer of material. In general, a business will purchase if it believes it has, or will have in a reasonable length of time, a customer to which it can sell the material after appropriate modification. If a single organization involves more than one function, the purchase is made on the basis of internally transferred information that one function of the organization has a material requirement which can be supplied by another function. There is no essential difference in the motivation to buy, only a difference in the certainty and source of the information that a purchase is warranted.

(6) Generation of Scrap Metal

Industrial generators of scrap metal have no choice but to somehow remove the scrap material they generate. They will, in general, remove scrap metal in the least costly or most profitable way available. The generators' choice is not whether to sell. They must sell, or give the material away, or pay someone to take it away. Although they can affect the amount of scrap metal generated by changes in their industrial process, and although they can affect the value of the material by changes in the sorting and storage procedures used, scrap metal generators will inevitably have scrap metal available for sale.

Because they deal in the accumulation of marginally valuable material into lots large enough to be sold, scrap metal collectors have a rather minor role in the market. Their choice is limited to the accumulation of material for potential sales at a later date. Depending on the cost of collecting and storing scrap metal, a particular collector's perception of the potential for sale at a profit within a reasonable time will determine whether scrap metal will be collected and stored or simply disposed of.

The bulk of the business of buying and selling scrap metal is handled by processors, brokers, and exporters. Unlike generators, which produce scrap metal at a rate that is independent of any perception of the potential for sale, these intermediate businesses have some control over the amount of scrap metal they will have for sale to consumers. This control is brought about by the amount of scrap purchased from generators and collectors. It has already been mentioned that the consumer of scrap metal controls the size of the scrap metal market. Thus, the consumer ultimately dictates the volume of scrap that will be purchased by processors and other intermediates. However, once the consumers make clear what their demands will be, the processors or brokers must decide whether to purchase additional material or reduce their current inventory.

A number of factors are involved in this decision. During times of decreasing demand, fixed costs cause pressures to maintain cash flow even to the extent of suffering short-term losses. Depending on its location and type of supplier, processors may be in the position to purchase scrap at prices low enough to allow them to increase their market share during periods of generally low demand. If so, their own particular business need not shrink. During times of increasing demand, the situation is simpler. A broker or processor will, if possible, offer prices that will generate increases in inventory sufficient to provide for throughput expanded to the capacity of the facility.

(7) Scrap Metal Consumer

It has already been stated that control over the scrap metal market size lies with the consumer. (Again, the term "consumer" as used in this appendix has been limited to those purchasing scrap metal and transforming it into some useful new metal material.) The consumers of this new metal material, however, ultimately control the size of the market. In the end, as previously mentioned, the overall economy dictates metal production requirements and, therefore, scrap metal requirements. To say that smelters, foundries, and other scrap metal consumers control the size of the market does not also mean that they have total discretion. They purchase scrap as they require it under the same constraints as those for brokers and processors. The difference is that their product is no longer scrap metal since it has been transformed into new products.

(8) Other Recycling Practices

Another notable practice for recycling or reusing metals is an operation such as Goodwill Industries. Goodwill is a not-for-profit organization dedicated to providing services and employment to disabled people through a nationwide system of accepting donated household items and repairing them for sale in retail establishments. Along with clothing and furniture, metal appliances are donated that would otherwise be thrown away. Although not strictly recycling, the Goodwill system (and similar "thrift store" operations such as Salvation Army, St. Vincent de Paul, and local charities) keeps a small number of large appliances actively operating and, thus, out of the landfills.

Another example of a similar practice is the operation of a flea market stocked by discarded white goods and other items in Berkeley, California. The facility is run by Urban Ore. Like Goodwill, the materials are donated to Urban Ore by citizens wishing to discard large items. The flea market is open to the public daily and reportedly grosses $25,000 per month.

Buyback centers for aluminum and steel beverage containers have blossomed into a standard sight in American cities and towns. Buyback facilities range from reverse-vending machines to mobile recycling units. The success of aluminum beverage container recycling on the consumer level has spurred recycling programs for other materials as well. The 1987 recovery rate for aluminum beverage containers was 50.5 percent.[17] Not all of the recovered beverage containers can be attributed to buyback centers. Container deposit laws in 10 states assess a deposit on aluminum beverage containers (along with glass and steel, in some cases), which is redeemable when the can is returned to the place of purchase or any other designated facility.

The potential certainly exists for expanding container deposit legislation to other states, or perhaps nationally, but it can be argued that buyback centers are already reaching the limits of effectiveness in recovering aluminum cans. For instance, a 72 percent increase in price for aluminum cans resulted in only a 3.4 percent increase in recycling levels between 1986 and 1987.[18]

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[17] Institute of Scrap Recycling Industries, "UBC Consumption Survey," Aluminum Association and Can Manufacturers Institute, 1987.

[18] Institute of Scrap Recycling Industries.

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TABLE OF CONTENTS

APPENDIX B

OTHER CONTRIBUTORS TO THE WASTE STREAM

Page

A. COMBUSTION ASH B.A-1
   1. Background B.A-1
   2. Ash Management Practices B.A-20
   3. Ongoing Research B.A-30
   4. Economics B.A-32
   5. Problem Identification B.A-33
   References B.A-36

B. DEMOLITION/CONSTRUCTION WASTE B.B-1
   1. Composition and Characteristics B.B-1
   2. Quantity/Volume and Toxicity B.B-2
   3. Human Health and Environmental Risks B.B-3
   4. Current Disposal Practices B.B-4
   References B.B-6

C. AUTOMOBILES B.C-1
   1. Introduction B.C-1
   2. Vehicle Availability Data B.C-2
   3. Vehicle Breakdown by Component B.C-6
   4. Vehicle Disposition B.C-11
   5. Current Recycling System B.C-12
   6. Barriers to Recycling B.C-24
   References B.C-29

D. SLUDGE B.D-1
   1. Introduction B.D-1
   2. Disposal Options B.D-5
   3. The Economics of Disposal Practices B.D-8
   4. Problems B.D-9
   References B.D-10

E. HOUSEHOLD HAZARDOUS WASTE AND SMALL QUANTITY GENERATORS B.E-1
1. Introduction B.E-1
2. Household Hazardous Waste (HHW) B.E-1
3. Small Quantity Generators (SQG) B.E-12
References B.E-17

F. USED OIL B.F-1
1. Background B.F-1
2. Current Federal Activities B.F-4
3. Current Management Practices B.F-7
4. State Programs B.F-10
References B.F-13

G. INFECTIOUS WASTE B.G-1
1. Introduction B.G-1
2. Availability of Data B.G-3

LIST OF TABLES

APPENDIX B

Table		Page
B.A-1	Summary of MSW Incinerator Statistics	B.A-5
B.A-2	As-Disposed Ash Weight	B.A-6
B.A-3	Municpal Solid Waste Incinerator Facilities	B.A-7
B.A-4	Materials Disposed of into the Municipal Waste Stream	B.A-8
B.A-5	Composition of MSW	B.A-10
B.A-6	Major Chemical Analysis of Moisture-Free Incinerator Residue	B.A-11
B.A-7	Ranges of Concentrations of Trace Inorganic Constituents in Flyash, Combined Ash, and Bottom Ash from Municipal Waste Incinerators	B.A-12
B.A-8	Dioxin Levels in Ash Residue	B.A-17
B.A-9	The Effect of Leaching Procedure on Leachate and Percentage of Heavy Metal in Ash that is Leached	B.A-19
B.B-1	California Study	B.B-2
B.C-1	New Car Sales, 1972-1990	B.C-5
B.C-2	Total Ferrous Metal in Average Ford Car	B.C-8
B.C-3	Materials Used in Average Ford Car, 1975 to 1990	B.C-9
B.C-4	Purposes for Purchasing a Deregistered Vehicle	B.C-13
B.C-5	Distribution of Recycled Vehicles by Source	B.C-14
B.C-6	Purchases by Dollar Volume of Parts from Discarded Autos	B.C-18
B.C-7	Sale by Type of Product in 1980	B.C-19
B.C-8	Means of Controlling Inventory	B.C-20
B.C-9	Shredder Residue	B.C-21

B.D-1	Heavy Metals in Sludge	B.D-3
B.D-2	Options for Sewage Sludge	B.D-5
B.E-1	Representative Household Hazardous Wastes	B.E-4
B.F-1	Concentration of Potential Hazardous Constituents in Used Oil	B.F-2
B.F-2	State Regulations/Programs for Used Oil	B.F-12

LIST OF FIGURES

APPENDIX B

Figure		Page
B.A-1	Ash as a Percentage of Waste Burned by Type of Facility	B.A-2
B.A-2	The Flow of Metals Through Municipal Solid Waste Incinerators	B.A-14
B.A-3	TCLP Leachate Concentration vs. pH	B.A-23
B.C-1	Average Weight of Plastics Waste per Junk Car	B.C-10

TABLE OF CONTENTS

APPENDIX B

A. COMBUSTION ASH

	Page
1. BACKGROUND	B.A-1
a. Major Sources and Volumes	B.A-1
b. Nature of Ash	B.A-6
c. Trends	B.A-18
d. Solubility of Heavy Metals	B.A-18
2. ASH MANAGEMENT PRACTICES	B.A-20
a. United States	B.A-20
b. International	B.A-27
3. ONGOING RESEARCH	B.A-30
a. U.S. EPA	B.A-30
b. Other U.S. Research	B.A-30
c. International Research	B.A-31
d. Research Needed	B.A-32
4. ECONOMICS	B.A-32
5. PROBLEM IDENTIFICATION	B.A-33
a. Toxicity	B.A-33
b. Landfill Capacity	B.A-34
REFERENCES	B.A-36

APPENDIX B

OTHER CONTRIBUTORS TO THE WASTE STREAM

A. COMBUSTION ASH

1. BACKGROUND

a. Major Sources and Volumes

When municipal waste is burned, residues are produced in the form of bottom ash, combined ash, flyash, and flue-gas cleaning products. All together, these residues constitute approximately 10 percent of the original waste in terms of volume, and approximately 25 percent in terms of weight.

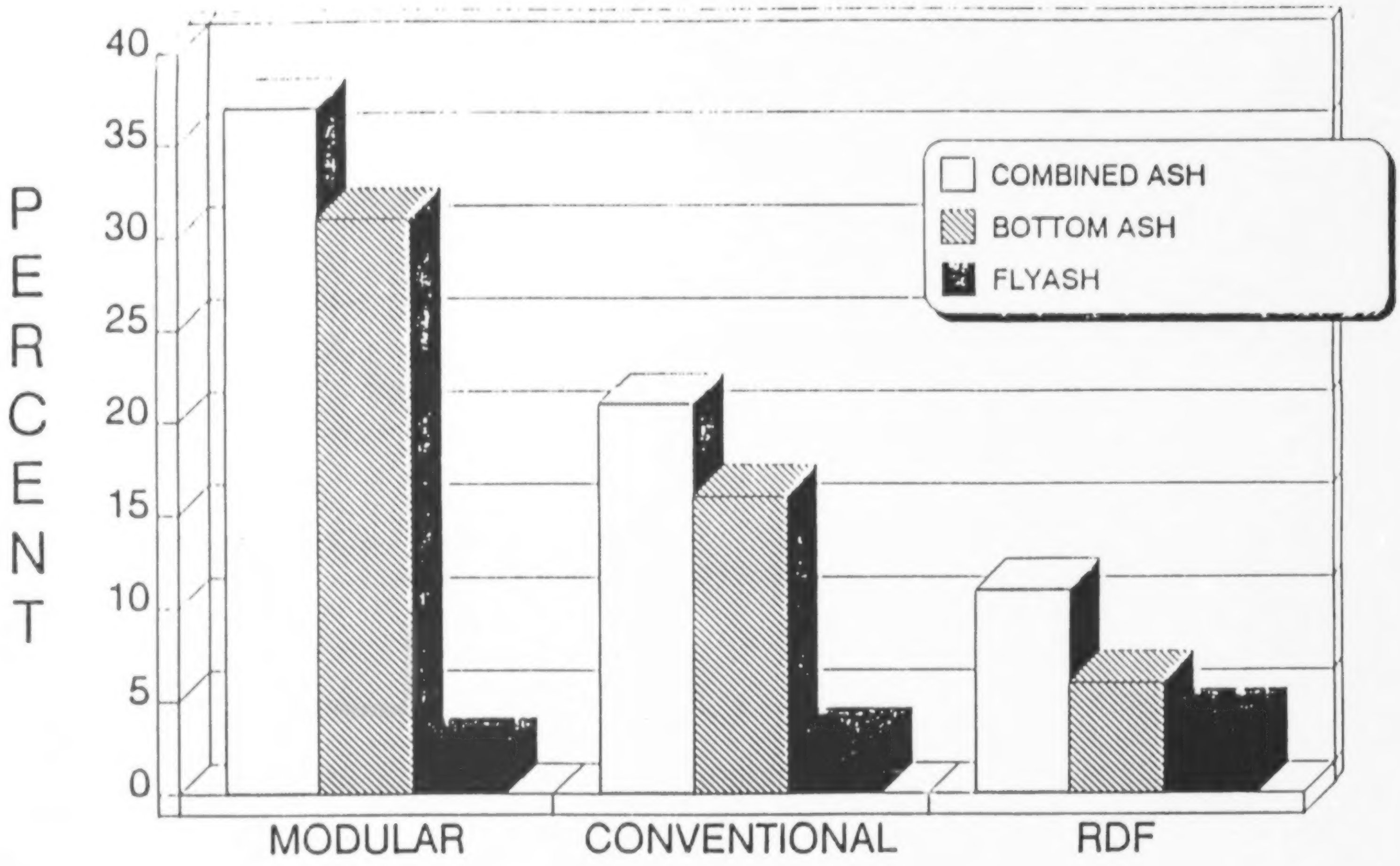
The type of combustion system determines the proportions of flyash and bottom ash generated. There are three types of municipal solid waste (MSW) combustors: mass burn, modular, and refuse-derived fuel (RDF). Waterwall and refractory-lined mass burn incinerators generate more flyash than starved-air combustion systems. Modular starved-air incinerators gasify the waste by supplying insufficient air for complete combustion in the primary chamber and by completing the combustion of these gases in a secondary chamber. This method results in less air turbulence and, therefore, less entrainment of ash particles in combustion gases. Suspension-fired fluff RDF systems generate the largest amount of flyash.

Typical weight distributions of ash residues produced by these three types of facilities are illustrated in Figure B.A-1.

Modular incinerators have the highest total ash because of the relatively high carbon and moisture content of the bottom ash. The combined ash shown includes flyash and boiler hopper

FIGURE B.A-1

ASH AS A PERCENTAGE OF WASTE
BURNED BY TYPE OF FACILITY



ash. The flyash and hopper ash total about 5 percent of the input waste.

Conventional mass-burn incinerators have less carbon and moisture in the ash, although the moisture content will depend on the type of ash handling system. Combined ash may be 20 to 25 percent of total waste, but flyash is less than 5 percent.

RDF plants remove 25 to 30 percent of the waste by processing before burning. Highly refined RDF has an average ash residue content of about 10 percent, of which half may be flyash, whereas shred and burn RDF systems may have 20 to 25 percent ash in the RDF itself. As with mass-burn systems, there is a difference in ash production between various RDF combustion processes. About 16 percent flyash is generated in a dedicated boiler (spreader stoker), with the remainder being a residue of bottom ash. RDF burned in a suspension-fired unit may have as high as 50 percent flyash and 50 percent bottom ash.

While RDF plants have a smaller quantity of ash residue, they have a residue from processing. The process residue sent to landfilling from RDF systems includes materials such as metal and glass, as well as some large combustibles. Separation of waste into two parts--one containing mainly combustibles and the other noncombustibles--is imperfect; hence there is an overlap between the two fractions of processed waste.

When acid-gas scrubbers are used, alkaline reagents such as lime are added to the flyash, typically in quantities close to the quantity of flyash, in effect doubling the flyash residue. The flyash plus residue may be 10 percent of MSW.

NUS Corporation and Versar, Inc., conducted several studies that are combined into a report for the U.S. Environmental Protection

Agency (EPA).[1] Table B.A-1 is from this EPA report and summarizes MSW incinerator statistics. The bar chart (Figure B.A-1), based on the statistics in Table B.A-1 and Table B.A-2, shows the weights of bottom ash, flyash, and combined ash generated as a percentage of waste burned by different types of facilities. This chart supports the discussion above.

The number of incinerator plants in operation in the United States and estimates of the residue produced by those plants varies from one study to another.

The recent NUS and Versar report indicated that there are 102 incinerator plants in operation. According to this report, the total MSW managed by these plants is 33,541 tons per day (TPD), which results in the disposal of 7,547 TPD (or 5,191 TPD on dry-weight basis) of ash residue.

According to an EPA report to Congress, there are 111 facilities in operation in the United States with the total design capacity of 48,971 TPD.[2]

According to a 1986 report by Governmental Advisory Associates, Inc., 122 existing resource-recovery facilities in the United States are either under construction, in shakedown, fully operational, or shut down temporarily or permanently. The total design capacity of those facilities that are operational or in shakedown (i.e., 70 facilities of the 122) is 34,564 TPD. If we assume an average operating capacity of 75 percent, the

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[1] Roffman, Haia K., and Wesley L. Bradford, Characterization of Municipal Waste Combustor Ashes and Leachates from Municipal Solid Waste Landfills, Moncfills, and Co-Disposal Sites, NUS Corporation and Versar, Inc., for U. S. Environmental Protection Agency, EPA 530-SW-87-028a, Washington, D.C., January 1988.

[2] U.S. EPA, "Municipal Waste Combustion Study: Report to Congress," June 1987.

TABLE B.A-1

SUMMARY OF MSW INCINERATOR STATISTICS

	Total	Modular	Conventional	RDF
Total facilities	102	51	48	3
With heat recovery	55	31	24	N/A
Total MSW managed (tons per day)	33,541	5,296	26,018	2,227
Total ash generated				
Ash disposed	7,547	1,943	5,374	231
Dry-weight basis	5,191	965	4,027	199
Bottom ash as disposed	2,930	1,630	1,175	125
Flyash as disposed	361	143	114	105
Combined ash as disposed	4,255	169	4,085	0
Number of facilities				
Disposal method				
Onsite landfill	23	12	9	2
Offsite landfill	73	36	36	1
Other/unknown	6	3	0	
Type of Landfill				
Monofill	36	16	18	2
Co-disposal	41	19	21	1
Other/unknown/not landfill	25	16	9	0
Ash disposed of				
Disposal method				
Onsite landfill	22.78%	3.37%	28.61%	50
Offsite landfill	77.22%	96.63%	71.39%	49
Other/unknown	0.00%	0.00%	0.00%	0
Type of Landfill				
Monofill	35.50%	25.97%	38.30%	50
Co-disposal	17.45%	46.14%	5.70%	49
Other/unknown/not landfill	46.57%	27.89%	55.32%	0

RDF = Refuse-derived fuel

Source: Roffman, Haia K. and Wesley L. Bradford. Characterization of Municipal Waste Combustor Ashes and Leachates from Municipal Solid Waste Landfills, Monofills, and Co-Disposal Sites, NUS Corporation and Versar, Inc., for U.S. Environmental Protection Agency, EPA 530-SW-87-028a, Washington, D.C., January 1988.

TABLE B.A-2

AS-DISPOSED ASH WEIGHT
(PERCENTAGE)

	Modular	Conventional	RDF
Bottom ash	30.8	4.5	5.6
Flyash	2.7	4.3	4.7
Hopper ash	3.2	15.7	--
Total	36.7	24.5	10.3
As-disposed moisture (percent)	50.0	25.0	14.0

RDF = Refuse-derived fuel.

facilities would produce about 5,700 TPD of ash.

Table B.A-3 shows statistics by state on the MSW incinerator facilities in operation.[3] This table indicates that there are 78 incinerator facilities in operation in 33 states, with the majority concentrated on the East Coast.

b. Nature of Ash

The incineration of MSW results in municipal waste combustor (MWC) ash residues. The composition of the incoming waste stream determines the composition of the residues from the incineration process. Table B.A-4 contains a summary of MSW stream data

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[3] National Resource Recovery Association (NRRA). "Resource Recovery Activities," City Currents, Vol. 6, No. 4, U.S. Conference of Mayors, NRRA, Washington, D.C., October 1987.

TABLE B.A-3

MUNICIPAL SOLID WASTE INCINERATOR FACILITIES
by EPA Region

EPA Region	Modular	Mass Burn	RDF
Region I	6	6	2
Region II	4	4	2
Region III	4	6	1
Region IV	4	9	2
Region V	2	6	4
Region VI	7	1	-
Region VII	1	-	-
Region VIII	1	1	-
Region IX	-	1	-
Region X	2	2	-
Total	31	36	11

Source: National Resource Recovery Association. "Resource Recovery Activities," City Currents, Vol. 6, No. 4, U.S. Conference of Mayors, Washington, D.C., October 1987.

Region I	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Region II	New Jersey, New York, Puerto Rico, Virgin Islands
Region III	Delaware, Washington, D.C., Maryland, Pennsylvania, Virginia, West Virginia
Region IV	Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee
Region V	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin
Region VI	Arkansas, New Mexico, Texas, Louisiana
Region VII	Iowa, Kansas, Missouri, Nebraska
Region VIII	Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming
Region IX	Arizona, California, Hawaii, Nevada, American Samoa, Guam
Region X	Alaska, Idaho, Oregon, Washington

RDF = Refuse-derived fuel.

TABLE B.A-4

MATERIALS DISPOSED OF INTO THE MUNICIPAL WASTE STREAM
(IN MILLIONS OF TONS PER YEAR AND PERCENTAGE)

Materials	1970		1984		2000	
	Tons	Percentage	Tons	Percentage	Tons	Percentage
Paper and paperboard	36.5	33.1	49.4	37.1	65.1	41.0
Glass	12.5	11.3	12.9	9.7	12.1	7.6
Metals	13.5	12.2	12.8	9.6	14.3	9.0
Plastics	3.0	2.7	9.6	7.2	15.5	9.8
Rubber and leather	3.0	2.7	3.3	2.5	3.8	2.4
Textiles	2.2	2.0	2.8	2.1	3.5	2.2
Wood	4.0	3.6	5.1	3.8	5.1	3.8
Other	--	0.1	0.1	0.1	0.1	0.1
Food wastes	12.7	11.5	10.8	8.1	10.8	6.8
Yard wastes	21.7	19.0	23.8	17.9	21.4	15.3
Miscellaneous inorganic wastes	1.8	1.6	2.4	1.8	3.1	2.0
Total	110.3	100.0	133.0	100.0	150.8	100.0

Source: Roffman, Haia K. and Wesley L. Bradford. Characterization of Municipal Waste Combustor Ashes and Leachates from Municipal Solid Waste Landfills, Monofills, and Co-Disposal Sites, NUS Corporation and Versar, Inc., for U.S. Environmental Protection Agency, EPA 530-SW-87-028a, Washington, D.C., January 1988.

statistics as of 1986.[4] These materials constitute the "feed" into incinerators and, once incinerated, yield MWC ashes.[5]

The chemical characteristics of MWC ashes have been determined in terms of inorganic constituents (including metals) and organics, including polychlorinated biphenyls (PCB's), polychlorinated dibenzo-p-dioxins (PCDD's), and polychlorinated dibenzo furans (PCDF's). An approximate, but typical, mass balance is shown in Table B.A-5.

Typical chemical composition of ash residue from mass-burn facilities is shown in Table B.A-6. The largest component by weight is silica, the primary constituent of glass, which is almost completely inert and constitutes about 40 percent of the total. Iron and aluminum oxides compose up to 28 percent of the residue by weight. Other metals (such as magnesium and zinc) are present in smaller quantities. Laboratories usually report metals as oxides since the analytical procedure oxidizes the original compounds to their respective oxides. Some of the metals may be present in MWC ashes in other chemical forms (such as sulfates, chlorides, and hydroxides).

Table B.A-7 lists the ranges of inorganic constituents analyzed by the different studies, including the EPA-sponsored NUS and Versar study of flyash, bottom ash, and combined ash. The data in this table clearly demonstrate that inorganic constituents (such as cadmium, lead, mercury, arsenic, and chlorides) are considerably more concentrated in the smaller particles of flyash than in the larger particles, which generally constitute the bottom ash.

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[4] Roffman and Bradford.

[5] Roffman and Bradford.

TABLE B.A-5

COMPOSITION OF MSW
(POUNDS PER MILLION POUNDS OF MSW)

Newspaper	34,000	**COMBUSTIBLES** 800,000 [80%]	Carbon	300,000			
Corrugated paper	90,000		Hydrogen	38,000			
Mixed paper	170,000		Oxygen	210,000			
Plastic film	53,000		Sulfur	700			
Rigid plastics	20,000		Chlorine	1,100			
Textiles	37,000		Nitrogen	1,260			
Food waste	66,000						
Wood	129,000		Moisture	158,000 [15.8%]			
Yard waste	105,000						
Sweepings	94,000		Ash	70,200 [7.0%]		Silica	30,000
						Iron	10,500
Ferrous metal	72,000	**INERTS** 202,000 [20%]				Aluminum	4,000
Aluminum	10,000					Calcium	3,600
Nonferrous	4,000					Potassium	1,572
Glass	28,000					Sodium	2,100
Miscellaneous inorganics	88,000					Silicon	600
						Zinc	49
						Lead	37
						Tin	18
						Chromium	1
						Nickel	2
						Copper	1
						Cadmium	1

TABLE B.A-6

MAJOR CHEMICAL ANALYSIS OF MOISTURE-FREE INCINERATOR RESIDUE

Material	Molecular Formula	Percent (a)	Percent (b)
Silicon dioxide (silica, primarily from glass)	SiO_2	59.8	43.4
Aluminum oxide (alumina)	Al_2O_3	9.8	13.2
Iron oxide	Fe_2O_3	4.0	15.3
Titanium dioxide	TiO_2	1.0	1.7
Calcium oxide (lime)	CaO	11.9	12.6
Magnesium Oxide	MgO	3.0	3.4
Zinc oxide	ZnO	0.4	-
Lead oxide	PbO	0.1	-
Copper oxide	CuO	0.1	-
Sodium oxide	Na_2O	6.1	3.5
Potassium oxide	K_2O	0.5	2.1
Lithium oxide	Li_2O	-	298 ppm
Sulfur trioxide (SO_4)	SO_3	0.9	1.0
Phosphorus pentoxide	P_2O_5	0.5	4.2
Other		1.6	-
Total		100.0	100.4[1]

Source:

(a) Based on a consensus of analyses performed on carbon-free residues. Collins, Robert J., "Promising Applications for Municipal Incinerator Residues," Proceedings of the Sixth Mineral Utilization Symposium, E. Aleshin, Ed., U.S. Bureau of Mines, IIT Institute, Chicago, May 2-3, 1978. Bulky metals have been removed.

(b) Average of four ultimate analyses during capacity testing, Westchester County Resource Recovery Facility. Cundari, Kenneth L., and Jeffrey M. Lauria, "The Laboratory Evaluation of Expected Leachate Quality from a Resource Recovery Ashfill," paper presented at Annual Spring Meeting of New York State Association for Solid Waste Management, Alexandria Bay, New York, May 19-20, 1986.

ppm = parts per million

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[1] Rounding off results of chemical analyses can result in total other than 100 percent.

TABLE B.A-7

RANGES OF CONCENTRATIONS OF TRACE INORGANIC CONSTITUENTS
IN FLYASH, COMBINED ASH, AND BOTTOM ASH
FROM MUNICIPAL WASTE INCINERATORS IN ug/g (ppm)

Parameter	Flyash	Combined Bottom Ash and Flyash	Bottom Ash
Arsenic	15-750	2.9-50	1.3-24.6
Barium	88-9,000	79-2,700	47-2,000
Cadmium	<5-2,210	0.18-100	1.1-46
Chromium	21-1,900	12-1,500	13-520
Lead	200-26,600	31-36,600	110-5,000
Mercury	0.9-35	0.05-17.5	ND-1.9
Selenium	0.48-15.6	0.10-50	ND-2.5
Silver	ND-700	0.05-93.4	ND-38
Aluminum	5,300-176,000	5,000-60,000	5,400-53,400
Antimony	139-760	<120-<260	
Beryllium	ND-<4	ND-2.4	ND-<0.44
Bismuth	36-<100		ND
Boron	35-5,654	24-174	85
Bromine	21-250		
Calcium	13,960-270,000	4,100-85,000	5,900-69,500
Cesium	2,100-12,000		
Cobalt	2.3-1,670	2.7-91	3-62
Copper	187-2,380	40-5,900	80-10,700
Iron	900-87,000	690-133,500	1,000-133,500
Lithium	7.9-34	6.9-37	7-19
Magnesium	2,150-21,000	700-16,000	880-10,100
Manganese	171-8,500	14-3,130	50-3,100
Molybdenum	9.2-700	2.4-290	29
Nickel	9.9-1,966	13-12,910	9-226
Phosphorus	2,900-9,300	290-5,000	3,400-17,800
Potassium	11,000-65,800	290-12,000	900-13,133
Silicon	1,782-266,000		1,333-188,300
Sodium	9,780-49,500	1,100-33,300	1,800-33,300
Strontium	98-1,100	12-640	81-240
Tin	300-12,500	13-380	40-800
Titanium	<50-42,000	1,000-28,000	3,067-11,400
Vanadium	22-166	13-150	53
Yttrium	2-380	0.55-8.3	

ND = Not detected at the detection limit
Blank = Not reported, not analyzed for

TABLE B.A-7

RANGES OF CONCENTRATIONS OF TRACE INORGANIC CONSTITUENTS IN FLYASH, COMBINED ASH, AND BOTTOM ASH FROM MUNICIPAL WASTE INCINERATORS IN ug/g (ppm)

(Continued)

Parameter	Flyash	Combined Bottom Ash and Flyash	Bottom Ash
Zinc	2,800-152,000	92-46,000	
Gold	0.16-100		
Chloride	1,160-11,200		
Country	USA, Canada	USA	USA, Canada

ND = Not detected at the detection limit
Blank = Not reported, not analyzed for

Source: Roffman, Haia K., and Wesley L. Bradford. Characterization of Municipal Waste Combustor Ashes and Leachates from Municipal Solid Waste Landfills, Monofills, and Co-Disposal Sites, Volume IV and Volume V, NUS Corporation and Versar, Inc., for U.S. Environmental Protection Agency, Washington, D.C., January 1988.

The wide range in concentrations results from differences in the composition of incinerated wastes and in the operating conditions of the incinerator. These conditions determine how much fine particulate is lifted from the combustion zone. Different furnace designs remove different amounts and sizes of particles; as a result, different levels of inorganics, including metals, remain in the removed ashes.

It is important to bear in mind where the metals go; specifically, how much goes in to flyash, how much goes to bottom ash, and how much is emitted. The fate of metals in MSW has been studied by Brunner and Monch in tests of two old-style plants with electrostatic precipitator (ESP) controls.[6] These data show that furnace design influences the amount of heavy metals lifted with flyash. Figure B.A-2 shows these data visually. The up arrow represents the emissions; the down arrow, the bottom ash; the horizontal arrow, the collected flyash.

Tests of the Prince Edward Island Incinerator (National Incinerator Testing and Evaluation Program) show that this starved-air incinerator lifted much less flyash and heavy metals than is typical for excess-air incinerators.[7]

Since the efficient emission control devices now required remove essentially all (99 to 99.99 percent) of the fine particulate, there is little difference in the composition of the flyash collected. There is, however, a substantial difference in the metals concentrations in particulate emitted by ESP's and

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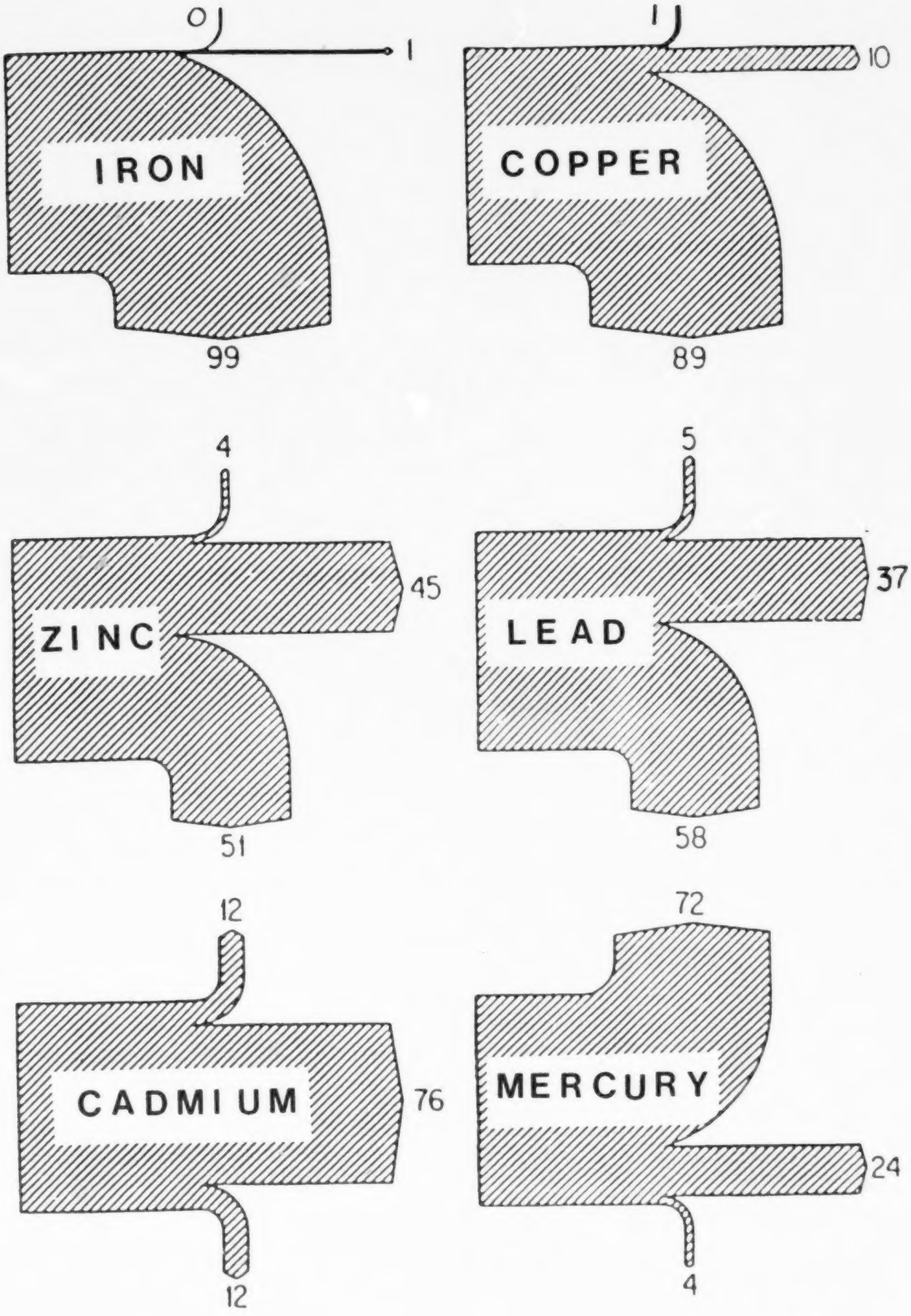
[6] Brunner, P. H., and H. Monch. "The Flux of Metals through Municipal Solid Waste Incinerators," Waste Management and Research, Vol. 4, 1986, pp. 105-119.

[7] NITEP, 1985. "National Incinerator Testing and Evaluation Program: Two-Stage Combustion (Prince Edward Island)," Report EPA 3/UP/1, Environment Canada, Ottawa, Ontario, Canada, September 1985.

FIGURE B.A-2

THE FLOW OF METALS THROUGH MUNICIPAL
SOLID WASTE INCINERATORS
(In percent)



Key:
Upward arrow - Air emissions
Horizontal arrow - Flyash
Downward arrow - Bottom ash

Source: Brunner, P.H., and H. Monch

fabric filters. Test data show that lead and cadmium concentrations in ESP particulate emissions are about six times the concentrations measured in baghouse emissions, apparently because of ESP's less-efficient removal of particles less than 10 microns in size.[8] Flyash collected by fabric-filter dust collectors (baghouses), which have a higher efficiency of removing smaller particles, would not contain significantly higher levels of heavy metals, however, because the overall quantities are so small.

A million tons of MSW (3-year consumption of a 1,000-TPD facility) typically contains about 2.4 million pounds of total lead, most of which is discharged in the bottom ash. About 430,000 pounds of lead would be in the combustible fraction discharged from the furnace with the flyash. The Quebec scrubber baghouse tests show that the emitted lead was from 1 to 5 pounds per million pounds.[9] There are essentially no emissions from the stack if a baghouse is used.

The data shown for scrubber/baghouses indicate that about half of the cadmium ends up in the bottom ash (the rest is in the flyash) with essentially no emissions.

Almost all of the organic compounds in MSW are destroyed in properly designed combustion chambers. However, organic compounds that survive the combustion process or form in the cooler parts of the system, including those with toxic potential (such as dioxins or furans), will be almost entirely contained in the residues.

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[8] Lane, W. R., and K. Khosla, "Comparison of Baghouse and Electrostatic Precipitator Fine Particulate, Trace Element, and Total Emissions," Bechtel Power Corporation, Houston, Texas, 1983.

[9] NITEP, 1986. "Air Pollution Control Technology," Report EPA 3/UP/2, Environment Canada, Ottawa, Ontario, Canada, September 1986.

Test data of dioxins in residues are limited; some typical data are shown in Table B.A-8. Several studies by the Canadian Ministry of the Environment performed at two municipal incinerators in Ontario identified trace amounts of dioxin and furans in the ash.[10] Tests of the Solid Waste Reduction Unit (SWARU) RDF-burning facility in Hamilton, Ontario, found significant amounts of PCDD in the RDF.[11] A mass balance of this (at that time) poorly operating facility showed that the flyash contained PCDD in quantities roughly equal to the PCDD in the RDF, while furans (PCDF's) were found at higher levels in flyash, but not in the RDF. Canadian tests of the Prince Edward Island modular incinerator showed dioxins and furans in the flyash, but they were not detected in bottom ash.[12]

The Swedish Ministry of the Environment, in their study of waste-to-energy facilities (June 1986), concluded that the dioxins which may be present in the ash are so firmly chemically bonded to the flyash particles that they will not leach out with water.[13] However, they can be removed by solvents that are likely to be present in hazardous waste landfills and possibly in MSW landfills.

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[10] Ozvacic, V., G. Wong, H. Tosine, R. E. Clement, and J. Osborne. "Emissions of Chlorinated Organics from Two Municipal Incinerators in Ontario," Journal of the Air Pollution Control Association, Vol. 35, No. 8, 1985, pp. 849-855.

[11] Envirocon. "Report on Combustion Testing Program at the SWARU Plant, Hamilton-Wentworth," ARB-43-ETGRD, Ontario Ministry of the Environment, Ontario, Canada, January 1984.

[12] NITEP, 1985.

[13] Ahlborg, U. F., and K. Victorin. "Impact on Health and Environment from Trace Organic Emissions," ISWA/WHO Seminar on Emission of Trace Organics from Municipal Solid Waste Incinerators, Copenhagen, Denmark, January 1987.

TABLE B.A-8

DIOXIN LEVELS IN ASH RESIDUE[1]

Sample	2,3,7,8-TCDD (ug/g)[1]
Nashville, Tennessee	0.4
Japan	0.1 -8.0
Japan (bottom ash)	0.01 -6.7
Italy	0.032-0.29
Saugus, Massachusetts	0.1 -0.2
Saugus (combined ash)	0.00 -0.02
North Andover, Massachusetts	0.1 -0.4
North Andover (combined ash)	0.02 -0.10

ND = <0.1 ng/g

Source: University of Massachusetts/Amherst. Incinerator Ash Management Project, March 30, 1987.

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[1] Flyash only, unless otherwise noted.

c. Trends

Based on the statistics from recent studies, the amount of ash residues generated by municipal waste combustion facilities in the United States is approximately 3 million tons per year.

Currently, 44 incinerator facilities are in different stages of development, with expected startup dates no later than 1992.[14] The projected total ash generated by these facilities will almost double the present volume of ash residue generated.

d. Solubility of Heavy Metals

The fraction of heavy metals that is soluble in water or acid rain water is an important factor in evaluating the risk of environmental contamination by leachate from ash residues.

Most of the available data on leaching of heavy metals from ash residues are based on fast-leaching tests using acid-spiked leaching fluid, as is done in the EPA extraction procedure (EP) and Toxicity Characteristic Leaching Procedure (TCLP) tests.

Data presented in the NUS and Versar report show the soluble metals content of leachate using the EP and TCLP fast-leaching procedures, and, for comparison, the results using the SW-924 leaching procedure that uses deionized (pure) water.[15]

Table B.A-9 shows the results for cadmium and lead leaching from flyash, combined ash, and bottom ash. With the fast-leaching procedures, flyash exceeded the limits; whereas in the

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[14] NRRA.

[15] Roffman and Bradford.

TABLE B.A-9

THE EFFECT OF LEACHING PROCEDURE ON LEACHATE (mg/l)

	RCRA Limit (mg/l)	Fast Leaching		Slow Leaching
		EP	TCLP	SW-924
Cadmium				
Flyash	1.0	6 - 18	0.02 - 17	0.005 - 0.12
Combined ash	1.0	0.06 - 0.8	0.03 - 3.3	0.005
Bottom ash	1.0	0.39	0.42	<0.01
Lead				
Flyash	5.0	5 - 25	0.003 - 15	0.03 - 0.13
Combined ash	5.0	2 - 34	0.66 - 30	0.03 - 0.06

PERCENTAGE OF HEAVY METAL IN ASH THAT IS LEACHED

	Fast Leaching	Slowing Leaching
Cadmium		
Flyash	82	0.03 - 0.8
Combined ash	6	0.03
Bottom ash	3	<0.07
Lead		
Flyash	1 - 6	<0.03
Combined ash	0.5 - 6	0.015
Bottom ash	6	<0.01

Source: Roffman and Bradford.

water test, the metals were far below the limits.[16]

The percentage of heavy metals present in the ash that was leached may be calculated from the test data as shown in Table B.A-9. The acid-leaching (fast) procedure removed 82 percent of the cadmium in the flyash when the water used was 20 times the ash weight, but only 3 and 6 percent of the cadmium in the combined or bottom ash. Less than 1 percent was removed when deionized water was used.

Only 1 to 6 percent of total lead was leached by the acid-leaching tests, and less than 0.015 percent by the deionized water tests.

2. ASH MANAGEMENT PRACTICES

a. United States

(1) Landfilling

The disposal method for nearly all ash residues from MWC facilities is landfilling. The ash is landfilled either together with MSW or by itself in a dedicated landfill (referred to as a monofill).[17]

Of the plants reporting an ash residue disposal practice in the Governmental Advisory Association, Inc. (GAA) report of 1986, 80.5 percent of the plants are landfilling ash without processing, 12.6 percent are processing the ash before landfilling, and 1.7 percent are using other disposal techniques such as concrete admixtures.

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[16] Roffman and Bradford.

[17] Roffman and Bradford.

The NUS report contains analyses of leachates from various sources. The composition of leachate from an ash quench tank, from MSW landfills not know to contain MSW-ash, co-disposal landfills, and monofills was found to be similar. These data show very low levels of toxic metals, but high levels of salts, especially chlorides. The pH is neutral to slightly alkaline (7 to 9). Leachates are disposed of in various ways, generally being sent to a water treatment facility where they are treated and diluted to reduce salt content to required levels.

The Marion County ashfill is the first site where combined ash is placed from a facility with acid gas control. The leachate has been found to be similar to the other leachates, except somewhat higher in salt content and pH, because of the lime added in the acid-gas scrubbing system.[18] Residues from plants with acid-gas controls using alkaline materials, such as lime as the neutralizing reagent, are more alkaline. These residues are likely to pass the EP test but may fail the distilled water test because of excessive alkalinity (pH exceeding 11) that mobilizes the lead (but not the cadmium). It is evident that these residues require careful control, management, or treatment to ensure that lead would not be released into the environment by mishandling.

(2) Treatment

The manner in which ash residues are handled within the combustion facility and the type of emission control system can have a significant effect on the characteristics of the ash. For example, the characteristics of mixed flyash and bottom ash are different according to whether the ash is passed through a water-quench tank or merely moistened, because chemical reactions take place and may make the heavy metals more or less soluble in the product.[19] Lead is highly soluble (hence can fail the EP test) at pH values below 5 and above 12 (see Figure B.A-3). By keeping the ash in a neutral pH range of 7 to 11, the solubility of lead can be minimized.

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[18] Marion County. Test data, Marion County Public Works Department, Oregon Department of Protection Agency, Salem, Oregon.

One form of ash treatment is to wash ash with water at a pH that dissolves lead, followed by treating the water to precipitate the metals into a sludge for separate use or disposal.[20] Tests by Feder and Mika and by others show that the soluble metals (which are primarily on the surface of flyash) are amenable to washing techniques.[21]

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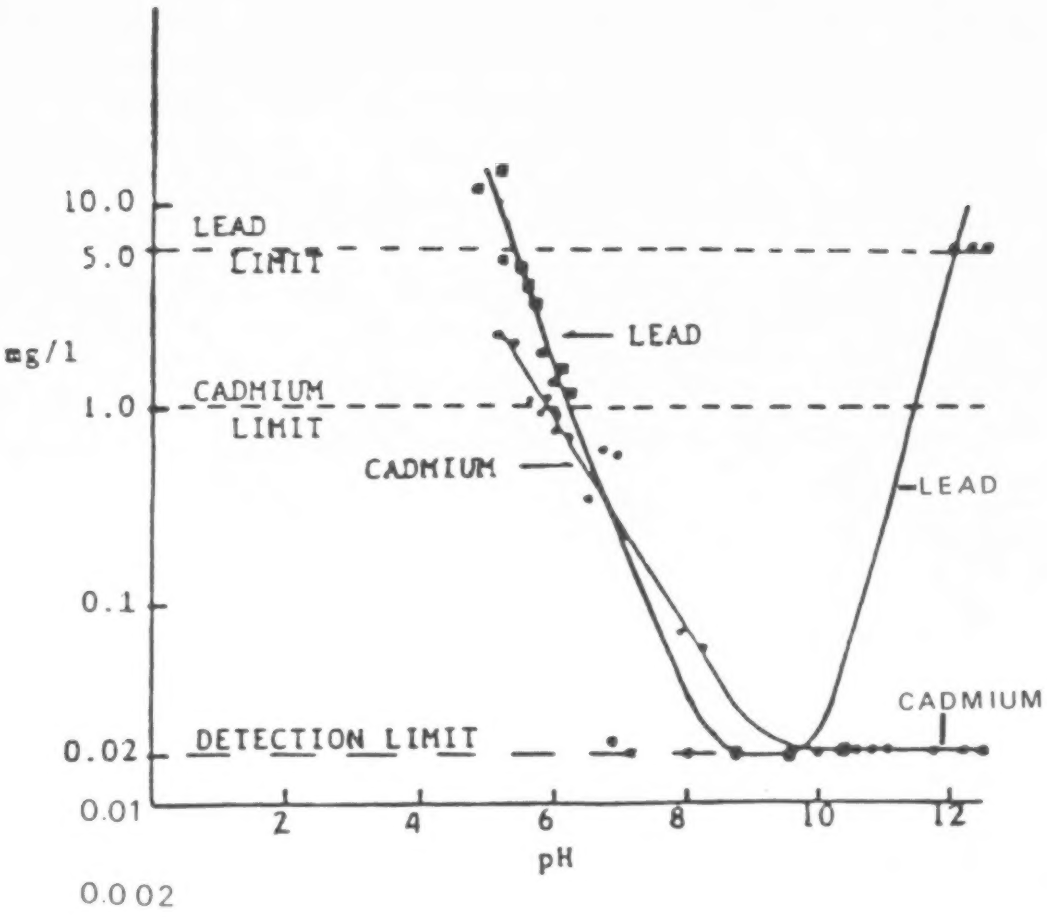
[19] Hjelmar, Ole.

[20] Reimann, D. "Gemeinsame umweltschonende Beseitigung von Filterstaeuben und Neutralisationsschlaemmen aus der Rauchgaswaesche--Bamberger Modell (Joint environmental protection elimination of filter dust and neutralization sludges from flue gas washing--Bamberg model)," VGB-Heft, Vol. 204, KABV Saabruecken s., Abfallwirtschaftliches Fachkolloquium, 25-26 April 1985; also Technische Mitteilungen H.d.T., Vulkanverlag Muellverbrennungsanlagen, 5, pp. 268-272.

[21] Feder, W. A., and J. S. Mika. "Summary Update of Research Projects with Incinerator Bottom Ash Residue," Executive Office of Environmental Affairs, Commonwealth of Massachusetts, February 1982.

FIGURE B.A-3

TCLP LEACHATE CONCENTRATION vs. pH



Source: Donnelly and Jons, APCA, 1987

Demonstrations of an ash-washing process in Germany show that cadmium can be recovered and sold along with lead, which is also precipitated out.[22] The remaining ash residues can be safely used for various purposes. The removed metals are marketable.

The natural alkalinity of the ash residues is normally sufficient to buffer acid rain in amounts equivalent to many years (25 to 200) of acid-rain leaching, as indicated by leaching tests performed by Cundari and others.[23]

A simple method of treating flyash is to add lime or Portland cement and water to the flyash and dampen it so that pozzalanic reactions that inhibit leaching take place.[24] This practice is common in Japan. Scrubber residues from combustion of MSW already contain lime; for combining these residues with flyash, it may be necessary to add only a small amount of additional lime to control the proportions of the mixture.

The mixing of flyash and scrubber residues with bottom ash results in a substantially different ash residue. This practice is carried out in Marion County where the mixed ash residue is disposed of in an ash monofill.[25]

Other treatments of ash residue that are being tested include chemical additions to the ash to turn soluble forms of metals into insoluble forms to prevent leaching.[26]

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[22] Vogg, H., A. Christmann, and K. Wiese. "The 3R-Process, an Element for Reduction of Pollutants in Refuse Incineration," Recycling International, Vol. 2, Karl J. Thome-Kozmiensky, Ed., Berlin, Germany, 1986.

[23] Cundari.

[24] Hartlen, J., and P. Elander. Residues from Waste Incineration: Chemical and Physical Properties, Report No. 172, Swedish Geotechnical Institute, Linkoping, Sweden, June 1986.

[25] Marion County.

(3) Recycling

As cited above, 1.7 percent of MWC ash presently is being used beneficially. The granular nature of bottom ash or combined ash meets the technical requirements for certain applications for which sand or gravel have traditionally been used.

Potential ash residues uses include

- Aggregate in cement or asphalt
- Road-base admixtures
- Concrete substitutes and mortar or grout
- Landfill cover

Incinerator residues have been used in the past as fill material in highway construction in the United States, but not on a continuous basis. Very little technical data on these installations have been kept or reported. However, the test asphalt highway near the Saugus, Massachusetts, RESCO plant is still sound.

As discussed above, ash has the ability to react with lime and moisture to form a concrete-like material. Using this ash, with some additions, to make cement blocks means that whatever contaminants are present in the ash are fixed in the blocks and thus may be unable to leach into the environment. Tests performed by Roethel and others have shown that the heavy metals do not leach from ash and concrete blocks when washed by water or seawater.[27]

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[26] Hartlen and Elander.

Uses in the United States include

- The ash residues from the Glen Cove (Long Island, New York) incinerator facility have been screened and used as a construction material.
- A private contractor has used screening equipment for many years on the landfill site of the Huntington (Long Island) incinerator facility to recover aggregate from ash residues for construction materials.
- The combined fly and bottom ash generated by the resource-recovery facility in Dade County, Florida, has been sold to Lone Star Industries, Texas, which is a cement producer.

The products that compete with ash in the marketplace--sand and gravel--are readily available, are relatively inexpensive, have established marketing and distribution systems, and are known to be benign environmentally.

Testing of ash for reuse has demonstrated its appropriateness in a number of applications. At this time, however, there are limited commercial applications in the United States of treated or reused incinerator ash.

Concerns that residues may contain toxic materials make it more difficult to market MWC ash as a raw material. A program of regular testing and pretreatment can help ensure safe use. Areas of the country with a steady demand for new roads and construction and that have limited available sand and gravel would provide the best potential markets. Roethel has estimated that all of the ash residues produced by Long Island incinerators could be used for blocks, roads, and reef construction.[28]

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[27] Roethel, Francis J., and V. T. Breslin. "Metal Leachability from Particulate and Stabilized Incineration Residues," APCA, Dallas, Texas, June 1988.

b. International

(1) Japan

The separation of noncombustible material from the waste stream in Japan reduces the volume of ash residue considerably. According to the Government's technical standards for new plants over 200 TPD, ignition loss--the amount of material allowed to pass through the furnace unburned--should be no more than 5 percent of the garbage volume introduced to the furnace.[29]

Several different methods of ash disposal are practiced in Japan. Flyash is often mixed with the bottom ash and disposed of together in a landfill that controls leachate. At a few plants, a stabilization process is used in which flyash is injected with 10 to 20 percent cement and water, then subjected to pressure, hardened into pellets or bricks, mixed with bottom ash, and sent to a lined landfill with a leachate collection system.

A vitrification process has also been used as a method of ash disposal. Vitrification is a form of stabilization that melts the ash into a glassy material from which metals do not appear to leach. The Sohka (Takuma) plant is equipped with ash melting equipment that processes incinerator ash residues into granulated glass slag. Ash is reduced to one-third of its original volume. Ash is melted at eight facilities in Japan, and the technique is gaining popularity.

(2) Sweden

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[28] Roethel and Breslin.

[29] Hershkowitz, Allen, and Eugene Salerni. Garbage Management in Japan: Leading the Way, INFORM, New York, 1987.

The use of slag (bottom ash) in Sweden is not a new idea. Environmental concern about using the slag formed at Swedish incineration plants as cover material and fill, among other applications, has led to an experimental program. These experiments have been carried out on a minor scale, and further research is necessary before general usage becomes a reality. At present, the greater part of slag is deposited at a waste disposal site.[30]

Southwest Scania Solid Waste Company, SYSAV, is a local authority-owned service company in Sweden. In 1984, SYSAV invested in a continuous sorting station in Malmo that processes raw slag. The slag from the SYSAV plant in Malmo is treated by screening and magnetic separation to recover scrap and roadbuilding material. Flyash is deposited at the landfill, together with residues from the slag separation.[31]

(3) Denmark

The authorities in Denmark issued instructions in 1982 governing the use of ash residues, permitting their use at distances greater than 30 meters from drinking water supplies.[32]

About half of the ash produced by Danish incinerators is reused as a construction material. The Danes have considerable experience with ash reuse applications and have established standards concerning use of slag and flyash from combustion of refuse and coal to facilitate their use in connection with building and construction work.

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[30] Modig, Steffan. Swedish View of the Ash Issue, National Environmental Protection Board, ox 1302, S-171 25 Solna, Sweden, March 23, 1988.

[31] Ahlborg and Victorin.

[32] Hjelmar, Ole.

(4) Holland

In Holland, some flyash is used as an additive to asphalt, but the remainder is sent to specifically designed landfills.

All of the bottom ash from incineration of municipal waste is converted into useful products in an ash processing plant that was started in 1986. From every ton of waste, 223 pounds of clinker, 21 pounds of scrap steel, and 7 pounds of nonferrous are recovered.[33]

The clinker is used as a base for roads, dikes, sound barriers, and wind screens. Clinker may be used only in applications 50 cm above the highest expected ground-water level to prevent leaching of heavy metals.

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[33] Bos, A. "Waste Management in Holland and the Largest Integrated Waste Processing Facility in the World," AIChE National Meeting, New Orleans, Louisiana, March 1988.

3. ONGOING RESEARCH

a. U.S. EPA

EPA has recently instituted or plans to undertake several major research programs on ash residues to provide a scientific data base for their regulatory activities. These include

- Several additional studies on ash and leachate characterization
- Studies on the effectiveness of ash monofills, including European experience
- Studies to determine the sources of lead and cadmium in the municipal waste and approaches for reducing the amount of these toxic metals in MWC ash
- Development of a ground-water monitoring scheme tailored to ash monofills
- Investigation of the effects of air pollution control technologies on the flyash characteristics
- Investigation of technologies for the treatment and reuse of MWC ash (e.g., use in construction materials)

b. Other U.S. Research

Research is currently under way by a variety of interested parties, either in conjunction with the EPA efforts listed above or independently. Industry is actively experimenting with potential reuse applications for ash. A partial, but not exhaustive, list of such studies gives an indication of the range and scope of current work:

- The University of New Hampshire is proceeding with a number of research projects related to ash landfills, leachate tests, and ash reuse.
- The Coalition for Resource Recovery and the Environment (CORRE) is working with the U.S. EPA to develop test methods that more accurately predict ash leachate

characteristics.

- Wheelabrator Technologies (formerly Signal Environmental Systems) has been working with the University of Massachusetts at Amherst over the past 10 years on ash reuse possibilities, such as growing media for plants and potential landfill covers.[34]

- The State University of New York at Stony Brook, Long Island, is testing cement blocks made from incinerator ash as building blocks for an artificial reef and for buildings aboveground (see Roether et al.).

- The New York State Energy Research and Development Authority (NYSERDA) is investigating ash characteristics and the potential for reuse (see Chesner).

- The American Society of Mechanical Engineers (ASME) Research Committee on Municipal and Industrial Waste has established an Ash Residue Research SubCommittee, which is working jointly with EPA to encourage research. This group and EPA's research office in Cincinnati conducted a workshop and plan to develop white papers and other publications in the field.

- Energy Answers Corporation of Albany, New York, has been working on developing markets for ash products for over 10 years, and is continuing research at the ANSWERS facility in Albany on aggregate and cement block production (see Donnelly et al.).

c. International Research

(1) Canadian Research

The Canadian government has sponsored extensive research under the NITEP and other programs to study ash-testing procedures and to analyze ash residues from plants with ESP's as well as scrubber/baghouses. Much of this work is in close cooperation with the U.S. EPA.

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[34] Feder and Mika.

(2) Worldwide Research

Similar efforts have been under way for years in Sweden, Denmark, Japan, Italy, Germany, Switzerland--in fact, everywhere that waste-to-energy facilities are operating. The Danes already have considerable experience with ash reuse applications as a construction material, and they have established standards. The Japanese have installed a vitrification system in the Sohka plant in Tokyo; while in Sweden, research is under way on ash use for road building and as a landfill cover.

d. Research Needed

Continuing research is needed on leachate (including wash water) treatment and disposal, and on ash treatment processes.

4. Economics

Because of the limited use of the incinerator ash residues in the United States (only 1.7 percent of total ash generated), information on economics is unavailable.

Some data are available on the costs of the vitrification process used in the Sohka (Takuma) plant in Japan. The plant is equipped with ash-melting equipment that uses fuel oil to process incinerator bottom ash into a granulated glass slag. The process is reported to cost $130 per ton of ash. The 2,550^{o}F temperature causes some metals to vaporize and be entrained in the flue gas. Electrostatic precipitators are used as an air-pollution-control device to trap particles in the flue gas and, therefore, to reduce heavy metal emissions. A study is now under way in Japan to treat flyash separately in electric ash-melting furnaces in order to stabilize it.

In three other plants in Japan, flyash is mixed with 10 to

20 percent cement and water to make pellets or bricks. This process adds 31 cents per ton of refuse processed.

Costs for landfill disposal currently vary considerably, depending on the local cost of landfill space. In addition, regulations upgrading the design, operation, closure, and postclosure of all landfills (whether for ash only or for co-disposal with raw MSW) will significantly increase landfill costs in many parts of the country. This issue is discussed in the next section.

5. PROBLEM IDENTIFICATION

a. Toxicity

The handling of ash from waste-to-energy plants is a problem that many jurisdictions are trying to resolve. There is considerable debate nationwide over how these residues should be tested and managed.

Two types of contaminants--metals and organic chemicals--have been detected in resource-recovery incinerator ash. The metals are contained in the incoming waste, and the organic contaminants may enter in the waste or may be formed as a result of the combustion process. The metals for which there are drinking water standards and thus also RCRA limits include: (1) arsenic, (2) barium, (3) cadmium, (4) chromium, (5) lead, (6) mercury, (7) selenium, and (8) silver. Of these, only lead and cadmium sometimes leache when subjected to certain aggressive leaching tests from the ash in quantities.

Trace amounts of dioxins, along with lead and cadmium, are the primary sources of concern about ash residue safety.[35] Low concentrations of organic compounds (such as pesticide residues or dioxin compounds in paper and wood treatment products), which are contained in the MSW, can be destroyed by the combustion process. However, dioxins can form in the cooler parts of the boiler from precursors found in the post-combustion gases and become attached onto flyash particulates, which are collected in the air pollution control equipment. The quantity of dioxins collected in flyash depends on the effectiveness of combustion.[36]

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[35] Roffman and Bradford.

b. Landfill Capacity

As a result of increased recognition of the potential environmental consequences associated with some landfills, State governments have begun to close many of them. For example, the State of New Jersey has closed over 58 percent of its landfills since 1977. Only one new landfill has since opened in the state, and several existing landfills have expanded. New York City has closed 14 of its 17 landfills over the past 20 years; California, New Jersey, and Florida have all initiated programs to minimize landfilling as a waste management strategy.[37]

Environmental regulations governing acceptable landfill design and operation are becoming increasingly stringent at the Federal and State levels, requiring such measures as liners, leachate collection, treatment, and removal, and ground water monitoring. Federal standards for landfills are currently being reviewed and may be strengthened. Costs for landfill units consistent with new standards could range from $45 to as high as $150 per ton for refuse disposed of, compared to costs from survey data of about $10 to $20 per ton for current landfilling.[36] This increased expense is coupled with an ever-worsening shortage of landfill space and the increasing rates of refuse generation.

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[36] Hasselriis, Floyd. "Optimization of Combustion Conditions to Minimize Dioxin Emissions," presented at ISWA/WHO Seminar on Emission of Trace Organics from Municipal Solid Waste Incinerators, Copenhagen, Denmark, January 1987, and in Waste Management and Research, Vol. 5, 1987, pp. 311-326.

[37] U.S. EPA.

As a result of shrinking landfill availability, the owners of some incinerator facilities have been forced to stockpile ash residues on the plant sites. Such ash piles, while "temporary," are a source of concern to residents and communities who fear that the exposed ash will be blown offsite by winds or transported by rain, which could carry contaminants into the local ground and surface waters. Dust from bottom and flyash piles can be minimized by frequent wetting. After drying, the ash may agglomerate so that the flyash is not free to blow away. The cementitious nature of the ash in this mixture binds it to the larger particles. The main concern is with surface runoff from the pile, which must be collected and properly disposed of to prevent seepage into the ground. Placing the pile on a paved surface so that all runoff and leachate can be collected and disposed of properly, constitutes an example of one good management practice.

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[36] U.S. EPA.

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TABLE OF CONTENTS

APPENDIX B

B. DEMOLITION/CONSTRUCTION WASTE

Page

1. COMPOSITION AND CHARACTERISTICS B.B-1

2. QUANTITY/VOLUME AND TOXICITY B.B-2

3. HUMAN HEALTH AND ENVIRONMENTAL RISKS B.B-3

4. CURRENT DISPOSAL PRACTICES B.B-4

REFERENCES B.B-6

APPENDIX B
OTHER CONTRIBUTORS TO THE WASTE STREAM

B. DEMOLITION AND CONSTRUCTION MATERIAL

1. COMPOSITION AND CHARACTERISTICS

Currently, the United States has 3.5 million buildings that are classified as Federal government buildings; private, nonresidential buildings; and residential apartment buildings.[1]

The demolition and construction wastes from these buildings, as well as renovation wastes from single-family residential units, include lumber, roofing and sheeting scraps, broken concrete material, asphalt, brick, stone, plaster, wallboard, glass, piping, and other miscellaneous building materials.[2] Included in this list of building materials is asbestos. Asbestos has been used in the construction industry because of its heat-resistant and durable qualities. It has been estimated that asbestos is found in 31,000 schools and 733,000 other public commercial buildings, primarily to insulate boilers and pipes.[3]

Other asbestos-containing products include friction products (brake linings), plastic products (floor tile and sheet), cement pipe and sheet, paper products (roofing felt, gaskets), textile products, and insulating and decorative products.

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[1] U.S. EPA 1988. "Report to Congress: Solid Waste Disposal in the United States," Vol. I, Draft Final (Revised), U.S. Environmental Protection Agency, April 15, 1988.

[2] U.S. EPA 1988.

[3] U.S. EPA 1985s. "Guidance for Controlling Asbestos-Containing Materials in Buildings," EPA 560/5-85-024, U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances, Washington, D.C., June 1985.

2. QUANTITY/VOLUME AND TOXICITY

The high volume of demolition and construction wastes is characteristic of the type of industry from which these wastes come. Steel, asphalt, concrete, brick, and other materials are typically very dense materials and are, therefore, extremely heavy when consolidated in a landfill. Unfortunately, the quantities of these wastes have not been reported in any recent studies. However, a study documented in 1977 concluded that demolition and construction wastes range from 0.12 to 3.52 pounds per capita per day (pcd).[4] Table B.B-1 reports the results of a California study in 1968.[5]

TABLE B.B-1

CALIFORNIA STUDY

Communities (people)	Demo./Const. Waste
fewer than 10,000	0.27 pcd
10,000 to 100,000	0.68 pcd
greater than 100,000	1.37 pcd

An urban average of 0.72 pcd was documented from a 1970 study.[6] With this average, the total quantity of demolition and construction wastes generated in the United States is estimated at approximately 31.5 million tons per year. This is equivalent to 22 percent of the municipal waste disposed of in 1986.[7]

Demolition and construction materials contain toxic substances such as lead pipes; polychlorinated biphenyls (PCB's) in capacitors and transformers; contaminated materials from leaking capacitors and transformers; and other kinds of potentially toxic materials such as paints, adhesives, treated lumber, and sheetrock.

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[4] U.S. EPA 1988.

[5] U.S. EPA 1988.

[6] U.S. EPA 1988.

[7] U.S. EPA 1988.

Because of the lack of scientific studies on the toxicity of these substances contained in demolition and construction material, it is difficult to estimate the quantity and concentration of these substances in landfills or their impact on the environment.

3. HUMAN HEALTH AND ENVIRONMENTAL RISKS

The most serious human health risks of demolition and construction wastes are those associated with asbestos-containing material. Asbestos is a fibrous mineral and, when disturbed, these fibers can become suspended in air for hours, thus increasing the extent of exposure of those fibers.[*] After long-term inhalation of these fibers, the various human health concerns include asbestosis (a chronic disease of the lungs), lung cancer, and mesothelioma (a cancer of the chest and abdominal membranes).

The environmental risks associated with the toxic substances of demolition and construction material are virtually unknown because a comprehensive study has never been completed on the toxicity and leaching potential of these wastes when mixed with other demolition and construction material.

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[*] U.S. EPA 1985b. "Asbestos Waste Management Guidance: Generation, Transport, Disposal," EPA 530/SW-85-007, U.S. Environmental Protection Agency, Office of Solid Waste, Washington, D.C., May 1985.

4. CURRENT DISPOSAL PRACTICES

Demolition and construction wastes are generally disposed of in demolition debris landfills. When the waste contains asbestos, landfilling is recommended as an environmentally sound isolation method, because asbestos fibers are virtually immobile in soil.[9] Other disposal techniques such as incineration or chemical treatment are not feasible because of the unique properties of asbestos.[10]

However, at least one company is proposing to destroy asbestos-containing material as well as flyash by using a technique called vitrification.[11] Vitrification processes will heat the asbestos to temperatures above its melting point so that the particles are converted into a glassy substance.

An acceptable disposal facility for asbestos wastes must adhere to EPA's requirements of no visible emissions to the air during disposal, or of minimizing emissions by covering the waste within 24 hours. The minimum required cover is 6 inches of nonasbestos material, normally soil, or a dust-suppressing chemical. In addition to these Federal requirements, many State or local governing agencies require more stringent handling procedures.[12]

The EPA and the Occupational Health and Safety Administration (OSHA) regulations require asbestos-containing material to be containerized as necessary to avoid creating dust during transport and disposal. The generally recommended containers are 6-mil-thick plastic bags, sealed in such a way to make them leak-tight.[13]

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[9] U.S. EPA 1985b.

[10] U.S. EPA 1985b.

[11] Mershon, Rand L., Project Director, Vitrifix, Inc. Personal communication, May 12, 1988.

[12] U.S. EPA 1985b.

The final closure of an area containing asbestos waste must cover the area with at least an additional 30 inches of compacted nonasbestos material to provide a 36-inch final cover. To control erosion of the final cover, it should be properly graded and vegetated.[14]

Unless a natural barrier adequately deters access by the general public, warning signs and fencing must be installed and maintained (40 CFR 61). A record is recommended for future landowners that asbestos waste has been buried at a site and that it would be hazardous to attempt to excavate that area. (Future regulations may require property deeds to identify the location of any asbestos wastes and to warn against excavation.)[15]

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[13] U.S. EPA 1985b.

[14] U.S. EPA 1985b.

[15] U.S. EPA 1985b.

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B. DEMOLITION/CONSTRUCTION MATERIAL

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TABLE OF CONTENTS

APPENDIX B

C. AUTOMOBILES

Page

1. INTRODUCTION B.C-1

2. VEHICLE AVAILABILITY DATA B.C-2
   a. Motor Vehicle Sales in the United States B.C-4
   b. Vehicle Registrations B.C-4

3. VEHICLE BREAKDOWN BY COMPONENT B.C-6

4. VEHICLE DISPOSITION B.C-11

5. CURRENT RECYCLING SYSTEM B.C-12
   a. Sources of Vehicles for Recycling B.C-13
   b. Auto Dismantler B.C-15
   c. Scrap Processor B.C-19
   d. Annual Energy Savings B.C-22

6. BARRIERS TO RECYCLING B.C-24
   a. Zoning B.C-24
   b. Replacement Parts B.C-25
   c. Public Ignorance of Industry Benefits B.C-25
   d. Environmental Regulations B.C-25
   e. Lack of Markets B.C-27
   f. Need for Research B.C-27

REFERENCES B.C-29

APPENDIX B
OTHER CONTRIBUTORS TO THE WASTE STREAM

C. AUTOMOBILES

1. INTRODUCTION

For years, the automotive industry in the United States has been the largest single user of iron and steel. In addition, the industry uses many other materials in the manufacture of motor vehicles, including aluminum and other nonferrous metals, plastic, glass, and rubber. Correspondingly, scrapped automobiles constitute the largest single source of reusable metals, plastic, and rubber in the United States. A large amount of lead batteries, used oil, and other automotive byproducts is also recovered.

The two major segments of the automobile recycling industry include the auto dismantler and the scrap processor. In the United States, approximately 11,200 auto dismantlers each year handle 7 to 8 million vehicles, resulting in annual receipts of $4 billion.[1] Half of the parts recovered from a scrapped motor vehicle by an auto dismantler are sold to garages, body shops, new and used car dealers, and auto rebuilders. The remaining hulk is sold to a scrap processor. The scrap processor generally shreds the hulk and sells the recoverable scrap metals, both ferrous and nonferrous, as well as other recovered materials.

Automobile scrap accounts for about one-third of the recoverable obsolete scrap, representing more secondary ferrous metal than any other segment of our economy. Obsolete scrap includes used appliances, railroad cars and tracks, steel beams from razed structures, and so forth. A total of 20 million tons (or 40 percent) of obsolete scrap recovered in 1983 was derived from automobile recycling.

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[1] Arthur D. Little, Inc. 1982 ADRA Survey of the North American Automotive Dismantling and Recycling Industry, prepared for the Automotive Dismantlers and Recycling Association, 1982, p. 2.

The United States is a major exporter of scrap metals, particularly iron and steel scrap. In fact, scrap is the principal commodity shipped overseas from the ports of New York and New Jersey.[2] In 1987 approximately 18 percent of the demand for U.S. ferrous scrap was for export purposes. Japan and the other Pacific-rim countries are major importers of iron and steel scrap. Turkey and Spain are also significant consumers of scrap. Other countries compete in the export scrap industry, among them the Soviet Union and Great Britain. In terms of the auto scrap industry, in particular, U.S. competitors on the world market include West Germany and the United Kingdom, with each shredding about 40,000 cars a week.

2. VEHICLE AVAILABILITY DATA

Worldwide motor vehicle production reached over 45 million units in 1986, a less than 1 percent increase over 1985 levels. More important, production posted in both years exceeded the 42.3-million-unit record set in 1978 and represented a 26 percent increase over a recession-related low of 36.1 million units produced in 1982. The 1986 production statistics also show that Europe displaced Japan as the world's leading auto producer. The United States ranked third. A competitive and rapidly developing automotive industry was clearly evident in South Korea, Brazil, Mexico, and Spain, as well as in some Eastern Bloc nations.

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[2] Phoenix Quarterly, Summer 1987. "Scrap Exports," Phoenix Quarterly, Vol. 19, No. 2, Summer 1987, p. 2.

Even more significant than production statistics are the changes that have occurred in the structure of the automotive industry over the past two decades. Shifting global economic and competitive conditions experienced in that timeframe have resulted in the international nature of the manufacture and sale of motor vehicles. It has become a fact that almost all major auto producers depend heavily on sales outside their own country. For example, of the worldwide sales reported by the Ford Motor Company in 1986, about 41 percent were derived from sales outside the United States. In addition to sales, this internationalized automotive industry increasingly purchases parts and subassemblies produced in many different countries, including South Korea, Spain, and Brazil. All domestic U.S. automakers use nondomestic suppliers of parts. In fact, the Automotive Parts and Accessories Association predicted in 1986 that "foreign sources will supply 58 percent of the auto parts for cars sold in the U.S. in 1989."[3] This represents a significant decrease over the 1970 market share of 70 percent for U.S. suppliers.

Another facet of the automotive industry that is becoming more international is the ownership of production facilities and the companies. GM has developed a joint venture with Toyota, Chrysler with Mitsubishi, and Ford with Mazda. Renault of France purchased a major share of American Motors, which was then purchased by Chrysler. The list is long and it changes daily. The institutional changes have taken place during a time of rapid technical change in the industry. These changes affected both the cars--smaller, lighter, more complex, and using new materials--and the production facilities.

The following discussion attempts to quantify the number of motor vehicles that would be available for recycling in the future. This information is based on an examination of available data regarding motor vehicle sales and registrations from the Wards 1987 Automotive Yearbook and other pertinent sources.

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[3] Wards Communications, Inc. Wards 1987 Automotive Yearbook, 49th ed., 1988, p. 42.

a. Motor Vehicle Sales in the United States

Reported annual retail sales of new, domestic passenger cars rose from the 5.8 million units sold in 1982 (the 15-year low point caused by the recession of the early 1980's) to 8.2 million units in 1986. This figure represents an increase of more than 36 percent. Domestic truck sales, aided by the introduction of new compact vans and trucks, rose from 2.2 million units in 1982 to more than 4 million units in 1986, an increase of approximately 80 percent.

In 1975, domestically produced cars accounted for 82 percent of the U.S. sales market for new cars. By 1985, imports had risen to 26 percent of new sales, and sales of new domestic cars (including those produced in Canada) had fallen to a market share of 74 percent. Past and projected annual sales of both new domestic and imported cars are shown in Table B.C-1. Sales of used cars have remained fairly consistent since 1979 (between 7.0 and 8.0 million units annually).

b. Vehicle Registrations

The number of privately owned cars and taxis registered each year has doubled in the 20-year period between 1960 and 1980 (72.8 million in 1960, 153.4 million in 1980). In 35 years, the number increased by a factor of nearly four (48.6 million in 1950 to 168.8 million in 1985). We can estimate that more vehicles are in operation than are registered, including farm vehicles or those illegally used. This theory has been confirmed by the Texas Division of Motor Vehicles, which estimates that 1.6

TABLE B.C-1

NEW CAR SALES, 1972-1990
(Thousands of Vehicles)

Year	Domestic	Imports	Total
1972	9,321	1,614	10,935
1973	9,670	1,748	11,418
1974	7,449	1,400	8,849
1975	7,050	1,499	8,549
1976	8,607	1,499	10,106
1977	9,104	2,074	11,178
1978	9,308	2,002	11,310
1979	8,328	2,331	10,659
1980	6,578	2,398	8,976
1981	6,206	2,327	8,533
1982	5,757	2,224	7,981
1983	6,795	2,387	9,182
1984	7,952	2,439	10,391
1985	8,205	2,838	11,043
1986	8,215	3,245	11,460
1987[1]	7,230	3,070	10,300
1988[2]	7,080	3,520	10,600
1989[2]	7,070	3,725	10,795
1990[2]	7,075	3,825	10,900

Sources: Ward's 1987 Automotive Yearbook, 49th ed., Wards Communications, Inc., 1988; also 1988 U.S. Industrial Outlook, U.S. Department of Commerce, International Trade Administration, Office of Automotive Industry Affairs, January 1988 (estimates and forecasts).

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[1] Estimate.

[2] Forecast.

percent of $10 million of revenues is lost because of unregistered motorists.*

According to statistics compiled by the U.S. Department of Transportation, Federal Highway Administration, motor vehicle registrations in 1986 totaled as follows:

o Automobiles	
-- Private and commercial	134,380,697
-- Publicly owned	1,050,415
Total	135,431,112
o Trucks and Buses	
-- Private and commercial	38,875,153
-- Publicly owned	1,885,074
Total	40,760,227
Grand Total	176,191,339

The 1986 motor vehicle registrations represented a 2.6 percent increase over 1985 levels.

3. VEHICLE BREAKDOWN BY COMPONENT

The energy crisis of the mid-1970's had a direct and significant impact on the automotive industry. Vehicles were rapidly downsized as a result of both the government-mandated, fuel-economy standards and the rising price of gasoline. The average dry vehicle weight (dvw) of U.S. cars in 1975 was 3,800 pounds. This contrasts significantly with the average dvw of 2,800 pounds for cars manufactured in 1985. However, we expect the average dvw will actually rise to 3,080 by 1990.[9] This increase has been projected on the basis of stable gas prices and consumer demand for larger, peppier cars.

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*Arner, Robert, and Diane Neill. Personal communication between Robert Arner and Diane Neill, Director, Division of Motor Vehicles, State of Texas, 1988.

The public's demand for smaller, lighter, and more fuel-efficient cars was accomplished in two ways. First, some basic design modifications were implemented. Second, steel components were replace with other, lighter materials.

The overall design strategy implemented by the automotive industry in its efforts to lower average dvw was to make vehicles more aerodynamic. This was achieved in two ways: The reduction in vehicle wheelbase and width and the use of reduced gauge steel in the body. For example, in 1975 a typical wheelbase for a larger car exceeded 120 inches; in 1987, few cars have a wheelbase exceeding 115 inches, the exceptions being Ford's Lincoln Town Car and GM's Cadillac Brougham.

The substitution of lighter materials, such as aluminum and plastics, for heavier materials has been an even more significant factor in reducing average dvw. High-strength steel, aluminum, and engineering plastics replaced the mild steel and cast iron formerly used in vehicle production. The decreasing consumption of steel by the automotive industry can be seen in Table B.C-2. These figures for Ford cars, which can be taken as representative of the industry, show a decline in the amount of iron and steel (ferrous metals) used in the average car, dropping from 3,010 pounds in 1975 to 2,052 in 1985. These data also indicate that the percentage of a car's weight attributable to ferrous metals dropped from 79.2 percent in 1975 to 73.3 percent in 1985. This figure roughly correlates with the reduction in demand for steel by the U.S. automotive industry that has occurred over the past

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[9] Berry, Bryan. "Automotive Materials: Steel Holds Steady, Plastics Keep Gaining," Phoenix Quarterly, Vol. 19, No. 1, Spring 1987, p. 2.

15 years. According to the American Metal Market, the demand dropped from 19 percent in 1975 to 17 percent in 1984.

TABLE B.C-2

TOTAL FERROUS METAL IN AVERAGE FORD CAR (1975-1990)

Year	Weight (Lbs)	Percentage of Volume
1975	3,010	79.2
1980	2,341	75.5
1985	2,052	73.3
1990	2,045	70.5

Source: Berry, Bryan. "Automotive Materials: Steel Holds Steady, Plastics Keep Gaining," Phoenix Quarterly, Vol. 19, No. 1, Spring 1987, p. 4.

Cars manufactured in the 1960's and 1970's contained between 60 to 100 pounds of aluminum. The average amount of aluminum used in domestic cars increased to 139 pounds in 1985. Today's cars can have as much as 150 pounds of aluminum each. The Aluminum Association estimates that this figure could rise to about 200 pounds per car by the early 1990's. Automakers have used aluminum outer body panels to cut the weight of some larger cars, including GM's Oldsmobile 98 and Ford's Lincoln Continental.[4] Aluminum has also been used in engine blocks, transmission cases, and other castings. Statistics developed by the Ford Motor Company on the use of various materials in the average Ford car are shown in Table B.C-3. These data confirm the two trends mentioned earlier: the reduction in weight of the average car in the U.S. fleet and the substitution of plastic and aluminum for ferrous metals.

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[4] Berry, p. 2.

TABLE B.C-3

MATERIALS USED IN AVERAGE FORD CAR, 1975-1990 (LBS)
(Most Typical of Domestic Cars)

	1975	1980	1985	1990 Projected
Milk Steel	2,280/60.0%	1,643/53.0%	1,400/50.0%	1,363/47.0%
High-Strength Steel	103/ 2.7%	217/ 7.0%	274/ 9.8%	334/11.5%
Cast Iron	627/16.5%	481/15.5%	378/13.5%	348/12.0%
Plastics	152/ 4.0%	217/ 7.0%	238/ 8.5%	319/11.0%
Wrought Aluminum	61/ 1.6%	78/ 2.5%	112/ 4.0%	145/ 5.0%
Cast Aluminum	19/ 0.5%	56/ 1.8%	36/ 1.3%	29/ 1.0%
Rubber	180/ 4.7%	150/ 4.8%	126/ 4.5%	125/ 4.3%
Glass	90/ 2.4%	88/ 2.8%	73/ 2.6%	72/ 2.5%
Lead	30/ 0.8%	29/ 0.9%	28/ 1.0%	27/ 0.9%
Copper/Brass	35/ 0.9%	30/ 1.0%	25/ 0.9%	20/ 0.7%
Zinc	35/ 0.9%	15/ 0.5%	11/ 0.4%	17/ 0.6%
Other	118/ 4.9%	96/ 3.1%	99/ 3.5%	101/ 3.5%

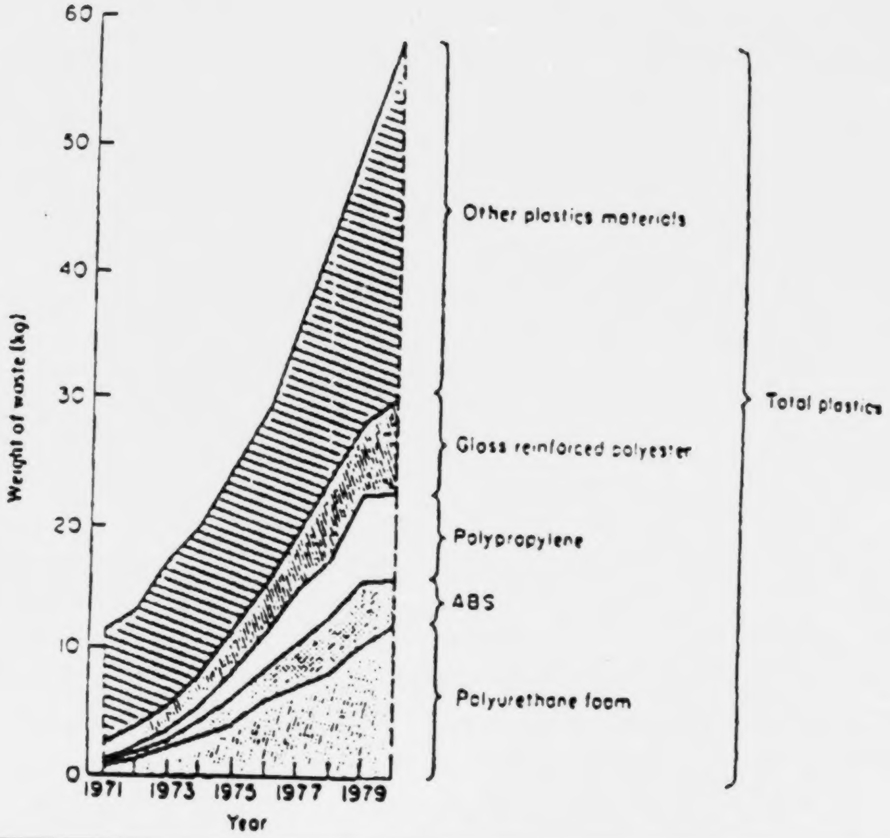
Source: Berry, Bryan. "Automotive Materials: Steel Holds Steady, Plastics Keep Gaining," Phoenix Quarterly, Vol. 19, No. 1, Spring 1987, p. 4.

By substituting plastic for steel, the weight of an individual car part can be further reduced by 40 to 50 percent. The Plastics Institute of America estimates that 120 pounds of plastics make up each unit; this figure should reach 250 to 300 pounds per unit by the year 2000.’ A similar projection for plastic use in automobiles has been made by Mahoney and Harwood. As shown in Figure B.C-1, the estimate for total plastic is specified by type.

’Dismantler's Digest. "Shredder Residue," Dismantlers Digest, Vol. 10, No. 1, January/February 1986, p. 31.

FIGURE B.C-1

AVERAGE WEIGHT OF PLASTICS WASTE
PER JUNK CAR



Source: Mahoney, L. R. and J. J. Harwood, "The Automobile as a Renewable Resource," Resources Policy, September 1975.

Because imports, particularly those from Japan, compose a large segment of existing and projected new car sales in the United States, it is important to note any differences between domestic vehicles and imports. The average American automobile is generally larger and heavier than most of its foreign counterparts. This difference is significant, given the quantity of imports that are and will be sold in this country, as shown in Table B.C-1. The average weight of a Japanese automobile is more than 800 pounds less than a comparable vehicle manufactured by Ford. Imported trucks and buses are also substantially smaller than those manufactured in the United States.[8]

4. VEHICLE DISPOSITION

Once the useful life of a motor vehicle has ended, the vehicle is retired. The average age of passenger cars in use has steadily increased during the past 35 years, with the average age of cars in service reaching 7.6 years in 1986. In 1970, the average age of passenger cars in use was only 5.6 years. A still closer examination of the age of cars in service in the past 2 years shows that the number of cars 16 hears and older has almost doubled since 1980. These cars account for nearly 7 percent of the U.S. fleet. A reason for this increase is attributable to changes in consumer habits because of rising costs of a new car.[9]

Automotive disposition rates have been developed and documented by a number of sources. However, it is quite difficult to get accurate cumulative or yearly figures for abandoned vehicles because of lack of information concerning what happens to autos once they are deregistered. The fluctuations in scrap recycling over the past several years, combined with the impact of new regulations on the industry, have also had an effect. The best data are available from R. L. Polk and Co.'s compilations of motor vehicle deregistrations. These data indicate that in 1986 an estimated total of 10,753,555 vehicles (passenger cars, trucks, and buses) were deregistered.

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[8] Robert R. Nathan Associates, Inc. Iron and Steel Scrap, Its Accumulation and Availability as of December 22, 1982, Part II, prepared for the Metal Scrap Research and Education Foundation, 1982, p. 24.

[9] U.S. Department of Commerce. 1988 U.S. Industry Outlook, January 1988, p. 38-2.

After deregistration, a vehicle can be disposed in a number of ways: sale to the recycling industry, abandonment, or even continued illegal operation. A report prepared for the Metal Scrap Research and Education Foundation supported the assumption that approximately 8 percent of deregistered vehicles might not be recoverable to the recycling industry.[10] Using this assumption, we conclude that about 860,280 vehicles deregistered in 1986 were not recycled or available for recycling. This figure can be considered conservative given increasing environmental regulations, and a soft scrap market could easily result in a loss rate of over a million vehicles.

Subtracting the estimated loss from the total deregistered vehicles results in an estimated 9.9 million vehicles recycled in 1986 alone. This number is consistent with estimates made for past years by the automobile recycling industry itself.[11]

5. CURRENT RECYCLING SYSTEM

The automobile recycling industry is a highly efficient part of our economy and uses modern communications and capital intensive equipment. Given the level of sophistication and the complex nature of this industry, the term "junk yard" is no longer considered appropriate, not is it endorsed by the industry.

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[10] Robert R. Nathan Associates, p. 66.

[11] Automotive Dismantlers and Recyclers Association. Profile: Automotive Dismantling Industry, 1982, p. 1.

The current recycling system for automobiles comprises two major segments: auto dismantler and scrap processor. Auto dismantlers provide for reuse of individual automotive components, whereas the scrap processor recycles materials back to the basic industries. However, there may be some overlap between these two industry segments.

a. Sources of Vehicles for Recycling

Motor vehicles enter the recycling system from a variety of sources and their ultimate disposition depends on age and make. As shown in Table B.C-4, the younger the car, the greater the chance for rebuilding; the older the car, the greater the chance it will be dismantled or scrapped.

TABLE B.C-4

PURPOSES FOR PURCHASING A DEREGISTERED VEHICLE

	Percentage of Vehicles Purchased For:		
	Rebuilding	Dismantling	Scrapping
1 to 5 Years Old	67.7	13.6	0.0
6 to 10 Years Old	5.3	8.8	13.9
11+ Years Old	1.2	0.4	16.5
Other	25.8	77.2	69.6
Total	100.0	100.0	100.0

Source: Arthur D. Little, Inc. 1982 ADRA Survey of the North American Automotive Dismantling and Recycling Industry, prepared for the Automotive Dismantlers and Recycling Association, 1982.

A 1982 study conducted by Arthur D. Little for the Automotive Dismantlers and Recyclers Association (ADRA) indicated that insurance-related sales, including salvage auction pools, accounted for 50.3 percent of recycled vehicles.[12] The distribution of recycled vehicles by source is shown in Table B.C-5 below.

TABLE B.C-5

DISTRIBUTION OF RECYCLED VEHICLES BY SOURCE

Source	Percentages
Insurance Contracts	21.8
Insurance Bids & Adjusters	8.6
Salvage Auction Pools	19.9
Individual Owners	27.6
Abandoned Vehicle Programs	2.4
Auto Dealers	4.4
Other Sources	15.3
Total	100.0

Each year, almost 27 million motor vehicles are involved in accidents. In many of these, the insurance carrier classifies the vehicle as a total loss. The owner is paid the book value of the vehicle, and the vehicle is sold for salvage at approximately 25 percent of book value. At a salvage pool, damaged vehicles are placed on display and salvage buyers bid on the vehicle. When a bid is accepted, the sale is completed and the vehicle is released to the buyer. Most late-model vehicles are bought by auto dismantlers. Older cars, unless they represent a specialty class such as sport cars, have little or not value above materials and generally are purchased by a scrap processor.

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[12] Arthur D. Little, p. 22.

These vehicles represent about 10 percent of the dismantling industry's sales.[13]

Some vehicles just wear out. Older wornout cars are either sold directly to a scrap processor or abandoned. Those abandoned in urban and suburban areas are collected sooner or later. However, the U.S. Bureau of Mines estimated in 1973 that between 15 and 18 percent of automobiles were discarded in rural areas on private lands in accumulations of 10 or fewer vehicles.[14] The report further estimated that half the vehicles abandoned in such situations could not be recovered. In a recent telephone conversation, Robert Adams, author of the U.S. Bureau of Mines' 1973 report, updated his conclusions by indicating the continued difficulty of obtaining good data as to the amount and manner of disposal of automobiles.[15] In addition, the remote location of many abandoned vehicles, coupled with some detitling laws and other legal restrictions, and the attitudes of owners can make recovery prohibitive in cost.

b. Auto Dismantler

Generally, an auto dismantler is a used parts dealer who purchases a deregistereed vehicle and removes potentially valuable components for sale to used car dealers, body shops, and individual customers. There are approximately 11,200 auto dismantlers in the United States, with annual receipts of approximately $4 billion (1982 dollars). The 1982 ADRA survey shows a majority of these operations, slightly more than two-thirds, are corporations and about one-third are either partnerships or solely owned.[16] On the average, each company employs 5 to 11 people and occupies a space from 1 to 100 acres of land. Roughly half of the automobiles handled are purchased from insurance companies at a median price of approximately $300. Half of the parts recovered from a scrapped motor vehicle are sold to garages, body shops, new and used car dealers, and auto rebuilders. The remaining hulk is sold to a scrap processor.

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[13] Phoenix Quarterly, Spring 1987. "Auto Dismantlers--Parts Recyclers and Scrap Suppliers," Phoenix Quarterly, Vol. 19, No. 1, Spring 1987, p. 5.

[14] Adams, Robert L.. An Economic Analysis of the Junk Automobile Problem, U.S. Bureau of Mines, Washington, D.C., 1973; also U.S. Department of the Interior, U.S. Bureau of Mines, Automobile Disposal: A National Problem, U. S. Government Printing Office, Washington D.C., 1967.

[15] Arner, Robert, and Robert L. Adams. Personal communication between Robert Arner and Robert L. Adams, U.S. Department of the Interior, U.S. Bureau of Mines, 1988.

An auto dismantler's operation consists of offices and a sales area, parts warehouse, and dismantling area. Dismantlers transport damaged vehicles from the salvage pool to their facility. Before disassembly, the vehicle is completely inventoried. Information is recorded as to condition, color, options, and mileage. Parts are marked for identification with vehicle year, make, stock number, and storage location. The inventory form is used by the counter sales staff as a reference in selling parts to customers.

During disassembly, the first item removed is the gas tank. This reduces the possibility of explosion and fire. The front-end assembly is generally removed as a unit. Disconnections are usually performed with impact tools, except where the bolts are considered expendable and are cut with a torch. The engine and transmission are lifted out in one piece. The complete unit is then positioned on a teardown bench in the warehouse where the various components are separated, including separation of the engine and transmission. The engine and transmission are placed in a high-pressure cleaning cabinet where petroleum-based solvents are used to remove excess dirt and grease. When the cleaning is completed, the components are tagged and placed on racks in the warehouse.

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[16] Arthur D. Little, p. 9.

Other saleable components removed from the car include the heater blower, windshield, windshield wiper motor, and doors. The radio is removed and boxed. Wheels and tires are washed and removed. Brake parts are removed and tested. All of these items are stored in the warehouse. The remainder of the car will be placed in the storage yard for a period of time in case additional parts are needed.

The average dismantler has a median inventory of 350 vehicles, which generally turns over in 90 to 120 days. The bodies no longer to be inventoried are sold to scrap processors. However, selling bodies depends on the type of vehicle--for example, a sports car would be kept longer because every nut and bolt is profitable. Auto dismantlers may also specialize (foreign, domestic, GM, etc.). According to the Maryland Energy Office (based on conversations with Maryland recyclers), approximately 50 percent of vehicle weight is used for parts sales and 50 percent is sent to scrap processors. This figure, of course, will vary with vehicle type (i.e., rebuilding, dismantling, scrap, and amount of accident damage).

Used parts dealers sometimes take parts from stripped wrecked autos and sell those used parts directly to retail customers in a display space in the dealer's shop. Many dismantlers are investing in chemical cleaning machines, which can transform greasy parts into clean, easy-to-handle components. Dismantlers are also buying bead-blasting equipment, which is used to removed rust and scale from metal parts.

Table B.C-6 lists (according to the 1982 ADRA survey) the purchases by dollar volume of parts from discarded automobiles.

TABLE B.C-6

PURCHASES BY DOLLAR VOLUME OF PARTS FROM DISCARDED AUTOS

Types of Customer	Percentage
Auto Rebuilders	9.9
Garages	15.1
Body Shops	14.6
Other Dismantlers	4.7
Telephone/Computer System	3.7
New Car Dealerships	5.4
Used Car Dealerships	4.2
Retail	27.2
Scrap Processor	9.8
Core Buyer	2.1
Other	3.3
Total	100.0

As can be seen, over one-third (36.8 percent) of the sales represent parts returned directly to the road through auto dealers or direct retail sales. Other significant purchasers include auto rebuilders, garages, body shops, and scrap processors.

Not surprisingly, used parts are the single most important product of the automobile recycling industry. These sell for one-third to one-half of the price of new parts. Both one-half scrap and cores represent less than 10 percent of the sales (Table B.C-7).

TABLE B.C-7

SALE BY TYPE OF PRODUCT IN 1980

Product	Percentage
Used Parts	75.3
Rebuilt Vehicles	7.6
New or Rebuilt Vehicles	6.8
Cores	3.3
Scrap	4.3
Other	2.7

In spite of major advances in formal methods of inventory control, the memory of the staff is still a major factor in the sale of used auto parts. Somewhat because of the increased complexity of new vehicles, many firms have more than one method of controlling inventory, as shown in Table B.C-8

Parts are readily exchanged between dismantlers throughout the United States by voice communication systems, computer networks, and so forth. Therefore, most dismantlers have access to inventory far beyond the boundaries of their own facility.

c. Scrap Processor

A scrap processor is a business operating from a fixed location that uses machinery and equipment for processing and manufacturing iron, steel, or nonferrous metallic scrap into prepared grades.[17] The resulting product is ferrous and/or

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[17] Institute of Scrap Iron and Steel, Inc. Metallic Scrap: The Manufactured Resource, 1984, p. 12.

TABLE B.C-8

MEANS OF CONTROLLING INVENTORY

- Inventory in the Memory of Staff
- Segregate Vehicles by Type
- Marked Bins or Shelves
- Parts Interchange Numbering
    - Hollander
    - Mitchell Manuals
    - Other
    - Ledger or File Cards
- Computer
- Other

Note: The average number of inventory control systems per firm is 3.4.

nonferrous metallic scrap suitable for melting purposes. The scrap processors' ferrous product is the principal feedstock of domestic electric-furnace steel minimills. It can also be exported for similar or other purposes.

The scrap processor uses a variety of machines to crush, cut, bale, and shred various types of metals. The key unit of a scrap-processing plant is the shredder, which can process a whole car. These units typically are driven by motors of up to 4,000 horsepower. Autos are shredded using steel hammers that can rip an auto into fist-size pieces of scrap in less than a minute. Shredded scrap then passes over magnetic drums, which separate iron and steel from other metals and nonmetallic material. Nonferrous metals are generally hand-picked from conveyor belts; however, a number of facilities use various density separators for this task.

There are about 180 to 200 shredders in the United States. A shredder can process from 25,000 to 250,000 autos a year, depending on its size, and can cost several million dollars. U.S.

shredder operators process approximately 150,000 cars each week, and in 1987 they had an estimated annual production of 12 million tons.

The residue remaining after recovery of recyclable products is called "fluff." A report from the Metal Scrap Research and Educational Foundation estimated that 550 to 850 pounds of residue or fluff--glass, plastic, dirt, and so forth--can be obtained from each automobile (Table B.C-9) or between 2 and 3 million tons based on 7.5 million hulks annually.[18] A Department of Energy (DOE) study published in August 1987, estimated that shredders generate 2.4 million tons of fluff each year.[19]

TABLE B.C-9

SHREDDER RESIDUE

600-900 lb.	Nonferrous/Nonmagnetic/Nonmetallic Metals
50 - 60 lb.	Nonferrous Metal
500-850 lb.	Glass/Plastic
2-3 million tons	Dirt

Source: "Shredder Residue," Dismantlers Digest, January/February 1986, Volume 10 (1).

A further analysis contained in the DOE study found that fluff had a mean higher heating value (HHV) of between 5,000 and 5,400 Btu/lb. Plastic, a major component of automotive shredder residue--as shown in the previous table--provides much of the fluff's fuel value. Consequently, the potential for using fluff as a fuel for power generation was further investigated. It was determined that a rotary kiln incinerator would be well-suited to burn fluff. A 3-day test burn of sample volumes of fluff was conducted using a rotary kiln incinerator equipped with secondary combustor, waste heat boiler, baghouse, and packed tower scrubber. The results of this test burn indicated that, on the average, 80 percent of the fluff volume and 50 percent of the fluff weight were reduced through combustion in a rotary kiln incinerator.

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[18] Dismantlers Digest.

[19] Hubble, W.S., I.G. Most, and M.R. Wolman. Investigation of the Energy Value of Automobile Shredder Residue, prepared for U.S. Department of Energy, Office of Industrial Programs, August 1987, p. 9.

To comply with environmental and safety regulations, the Institute of Scrap Iron and Steel, Inc. (ISIS), has developed for shredders a list of specific items that must be removed from vehicle hulks before receipt at the processor's gate or else the entire load will not be accepted.[10] These items include batteries, gas tanks, extra mufflers and tailpipes, closed containers, dirt, and debris. The intent of this guideline is to maintain the nonhazardous nature of generated fluff. In addition, ISIS has developed another list of 25 materials that require informed consideration by processors before acceptance. The items on this list include wire and cable (because of lead content), white goods (because of cadmium content), and hospital scrap.

d. Annual Energy Savings

In terms of energy savings potential, the Maryland Energy Office has evaluated recycling of motor vehicles in the following areas:

- Extended vehicle life
- Reuse of parts
- Recycling of materials
- Maintaining fuel efficiency

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[10] Cutler, Dr. Herschel. "The Generation, Preparation, and Consumption of Metallic Scrap--A Mandate for Change," Dismantlers Digest, Vol. 11, No. 2, March/April 1987, p. 8.

The results of the analysis show that the total energy savings that could be derived from recycling motor vehicles equalled 200.4 X 10^6 Btu per vehicle. This is equivalent to 1,600 gallons of gasoline or over 1,400 gallons of home-heating oil. The details of the analysis are summarized below.

(1) Extended Vehicle Life

Reusing parts for the average car would triple its life, thus saving 60 percent of the 21 barrels of oil required to manufacture each vehicle. The energy that would be saved by tripling the life of the car is 345,000 barrels per day of oil equivalent. Maximum recycling of the auto's parts, as noted, would save another 30 percent, or 173,000 barrels per day of oil equivalent. Total energy savings in this area would be 119.1 x 10^6 Btu. (Note that 140,000 Btu is equal to one barrel of No. 2 fuel oil.)

(2) Reuse

About one-half of an auto's weight can be reused for parts, eliminating the need to mine or manufacture new metals for new parts. The energy costs for manufacturing 10 million cars annually is 575,000 barrels per day of oil equivalent or 22.8 X 106 Btu.

(3) Recycling

Again, one-half of an auto's weight can be used for metals recycling. (Note that there is double counting when parts that are reused eventually wear out and thus are again available for recycling.) Recycling scrap can save 95 percent of the energy required to process aluminum, as well as the additional energy associated with processing iron, steel, lead, and zinc. Total energy savings associated with this category would be 15.4 X 106 Btu.

(4) Fuel Efficiency

Savings in fuel efficiency can be accomplished by replacing worn-out parts with recycled parts (engines, transmissions, carburetors, distributor heads, fuel pumps, etc.). These types of efforts would result in an efficiency improvement of 10 percent for every five vehicles. Based on the average fuel use of a U.S. car (690 gallons of gasoline), energy savings in this category would be approximately 43.1 X 10^6 Btu.

6. BARRIERS TO RECYCLING

As noted above, tracking systems to account for automobiles disposed of in the United States are not comprehensive; thus reliable data on the percentage reused/ recycled are problematic. Barriers to vehicle recycling are summarized in the following sections.

a. Zoning

Automotive recyclers, including both dismantlers and scrap processors, face a major barrier in locating a new site for vehicle salvage. Most existing operations were established 20 to more than 30 years ago. With increased population and urbanization, property values have soared; thus increased property taxes and escalating land prices have created more restrictive zoning provisions. Consequently, it is difficult to find affordable property and then obtain appropriate zoning approvals. To some degree this difficulty is a result of the public image problem associated with previous "junkyard" operations. Efforts to site an auto recycling operation can often encounter the "not in my backyard" mentality. As a result, most salvage operations are located in rural, sparsely populated areas, resulting in increased transportation costs and limited marketing opportunities. Also, new auto recycling operations may never start up because of the inability to locate a site.

b. Replacement Parts

New aftermarket parts--especially foreign ones--are numerous and inexpensive, providing intense competition to reused or rebuilt parts.

c. Public Ignorance of Industry Benefits

In areas where there is strong commitment to recycling and/or energy conservation, public agencies have worked with the automobile recycling industry to improve its image. Most consumers are unaware of the overall benefits of the industry. In particular, the Maryland Energy Office has created an award-winning promotional program with Maryland Auto and Truck Recyclers.

d. Environmental Regulations

One of the greatest barriers to increased automobile recycling has been compliance with environmental laws, guidelines, and codes. The major concern is that many items associated with recycling of auto hulks, in particular, have been identified as potential sources of hazardous materials. Such items include gas tanks; batteries; used oil; solvents; mufflers and catalytic converters; painted, coated, and plated scrap; and auto brake drums. These items are potential sources of asbestos and of lead, cadmium, or other heavy metal contaminants.

As stated previously, ISIS has developed guidelines for automobile recyclers that, if applied, would result in shredding operations rejecting auto hulks containing such items. Unfortunately, the potential sources of hazardous materials listed above will probably be co-disposed with municipal solid waste

(MSW) in landfills. To continue to handle these materials, an automobile recycler must comply with the inventory and manifesting system required under the Resource Conservation and Recovery Act (RCRA). This compliance can result in increasingly costly administrative and overhead problems. The insurance needed to cover handling "hazardous wastes" is an additional cost burden and is often difficult to obtain as well.

Another barrier to the automobile recycling industry occurs when automakers design cars without regard for recycling. For example, cadmium coating on certain bolt heads for the underbody of autos or the use of other hazardous heavy metals in other vehicle components make auto hulks potential sources of hazardous materials.

Confusion as to what the regulations are, what they mean, and how to comply with them is also a problem for the auto recyclers. Small quantity generator (SQG) regulations apply to much of the material discussed above. The cost and volume of the associated paperwork can be overly burdensome to small family-run operations--described as "19th century operators dealing with 21st century problems" by one industry representative. Most recyclers have little college education; many inherited yards from their families and have been doing things the same way for years or even generations. Despite assistance from trade groups, interpreting these laws and regulations and then following the rules can be overwhelming. Because State and Federal regulations are in constant flux, and regulators often cannot interpret their own regulations, small operators may choose to ignore the rules or to close up the business entirely. The lack of markets for the hazardous waste products that result from scrapping autos may contribute to closing these businesses because the cost of correct disposal becomes prohibitive.

e. Lack of Markets

As the supply of materials increases, the demand for such scrap goods usually decreases. Markets for recycled materials are usually soft except for certain metals (e.g., aluminum, copper). The more deleterious the materials (e.g., lead-acid batteries, used oil, solvents, and asbestos), the more difficult it is to find a market or to otherwise properly dispose of the material. These products can become mixed into the production process; for example, a battery can get into a shredder or solvents can be mixed into used oil. Another possible destination for such unsaleable items is the landfill. The net result of such mistakes is a more costly, hazardous, and dangerous situation.

f. Need for Research

The automobile is a complex and difficult mix of materials to track from the showroom floor through disposal, recycle, and/or reuse. How many cars are abandoned? What happens when automobiles are not recycled? The existing automobile recycling industry is capable of recycling some 6 to 9 million auto hulks every year, along with up to 80 million lead-acid storage batteries. It can recycle as much as 50 million tons of ferrous scrap, 12 to 15 million tons of paper, and 2 million tons each of aluminum and copper scrap (not to mention glass and plastics).

Data are needed on the autos NOT captured by the recycling industry, as well as on research and development of new or improved methods of handling potentially hazardous materials.

It is significant to note that the DOE is currently funding Argonne National Laboratory to prepare a study on the automobile recycling system. The three major topics to be focused on include

- Impact of the presence of zinc contaminants on system waste disposal options
- Impact of antimony in foreign aluminum castings on system waste disposal options
- System study and evaluation

This study should be completed in 1989.

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TABLE OF CONTENTS

APPENDIX B

D. SLUDGE

Page

1. INTRODUCTION B.D-1

2. DISPOSAL OPTIONS B.D-5
   a. Landfilling B.D-5
   b. Land Application B.D-6
   c. Incineration B.D-7
   d. Ocean Disposal B.D-8
   e. Monofills B.D-8

3. THE ECONOMICS OF DISPOSAL PRACTICES B.D-8

4. PROBLEMS B.D-9

REFERENCES B.D-10

APPENDIX B

OTHER CONTRIBUTORS TO THE WASTE STREAM

D. SLUDGE

1. INTRODUCTION

The principal byproducts of water and wastewater treatment are the solids that are removed from the water during treatment. These solids, known as sludge, can be disposed of in a variety of ways, including in a municipal solid waste landfill. Typically, the sludge is first processed before disposal to reduce its water content, reduce the volume of solids, and destroy disease-causing organisms. There are three types of sludges that can be disposed of in municipal landfills: nonhazardous industrial sludge, municipal sewage sludge, and water treatment sludge.

Nonhazardous industrial sludges (sludges that are not listed as hazardous wastes under the Resource Conservation and Recovery Act, known as RCRA) are produced by the wastewater treatment processes at companies that do not contribute toxic chemicals or heavy metals to their wastewaters in significant quantities. When such chemicals or metals are added to wastewater in substantial amounts, they can become part of the sludge. Sludges that contain significant quantities of these potentially hazardous substances may be hazardous wastes under RCRA and, if so, cannot be disposed of in a municipal landfill. The remaining industrial sludges can be disposed of in municipal landfills; however, many companies elect to dispose of sludge on their own sites. One report suggests that the industries most likely to dispose of nonhazardous sludges in municipal landfills are[1]

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[1] SAIC. Summary of Data on Industrial Nonhazardous Waste Disposal Practices, prepared for the U.S. Environmental Protection Agency, 1985.

- Food processors
- Leather tanning
- Pharmaceuticals
- Textiles

The quantity of nonhazardous sludge generated by these industries and disposed of in municipal landfills is not known. We would expect that such disposal is a very localized decision based on the constituents of the sludge, cost of transportation and disposal, availability of capacity, and willingness of the landfill operator to accept the waste.

Municipal sewage sludge, including at times septic tank sludge, is a common component of the waste stream to municipal landfills. Over 40 percent (2.9 of 7.0 million dry tons per year) of all sewage sludge is disposed of in municipal solid waste landfills. Sewage sludge is created as a byproduct of sewage treatment at 15,000 publicly owned treatment works (POTW's) around the country. The sludge consists of a mixture of organic and inorganic solids that are removed from the sewage during physical and biological processes. These sludges are often treated to remove water and disease-causing organisms before landfilling or other disposal.

Municipal sludges can contain relatively high concentrations of heavy metals (although usually not high enough to be hazardous wastes under RCRA) and other contaminants as a result of industrial discharges to public sewers and storm-water collection in combined sewers. These contaminants can cause human health or environmental concerns when considering sludge should be falling nationwide with the issuance of pretreatment regulations that control industrial discharges and with the efforts in many cities to separate storm water from sewage. The composition of heavy metals in sludge has been reported as in

Table B.D-1.[2]

TABLE B.D-1
HEAVY METALS IN SLUDGE

Component	Mg per Kg (parts per million) Range	Median
Lead	13-26,000	500
Zinc	101-49,000	1,700
Copper	84-17,000	800
Nickel	2- 5,300	80
Cadmium	1- 3,410	10
Chromium	10-99,000	500

Source: SCS Engineers, "Use and Disposal of Municipal Waste Water Sludge", U.S. EPA, Intra-Agency Sludge Task Force, September 1984.

The final type of sludge of interest if from water treatment to remove contaminants from drinking water supplies. These sludges contain largely inorganic material combined with chemical complexes of aluminum, calcium, or iron. (The chemicals are added during treatment to facilitate removing solids.) These sludges are also frequently disposed of in municipal landfills.[3] Other disposal options include putting the sludge in the sewer, returning the sludge to the water source, and putting the sludge in lagoons or placing the sludge in drying beds onsite. The quantity of sludge generated from water treatment each year is 3.5 million dry tons. How much of this sludge is sent to municipal landfills is not known.

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[2] SCS Engineers. Comprehensive Sludge Study, prepared for U.S. Environmental Protection Agency, December 27, 1978.

[3] American Water Well Association. "Sludge: The Disposal Dilemma," American Water Well Association Journal, June 1987.

The three types of sludges described above are similar in some respects and very dissimilar in others. The most important similarity is water content. When sludges are removed from treatment processes, they contain virtually all water (i.e., 99 percent). For most disposal options, therefore, sludges are first dewatered to achieve a sludge that is 15 to 40 percent solids. Sewage sludges and some nonhazardous industrial sludges are then processed further to stabilize the organic fraction of the sludge and to destroy pathogens through heat treatment, digestion, composting, or chemical addition. The more inorganic sludges from industry and water treatment do not require this stabilization step before disposal.

While we do not know how much industrial and water treatment sludge is managed under each of the currently available disposal options, Table B.D-2 provides an estimate of how each option is used for sewage sludge.[4]

Most of the disposal options presented for sewage sludge are also available for nonhazardous industrial and water treatment sludges. Therefore, each disposal option is discussed below to describe current practices, special considerations by types of sludge, and health and environmental concerns.

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[4] Nichol, Debora. Telephone conversation with Debora Nichol, U.S. Environmental Protection Agency, Water Office Economic Analysis Branch, who is preparing the economic analysis of the pending sludge regulations, April 1988.

TABLE B.D-2
OPTIONS FOR SEWAGE SLUDGE

Disposal Options	Millions of Dry Tons per Year	Percentage of Total
Landfilling	2.9	42
Land Application	1.7	25
Incineration	1.5	22
Ocean Disposal	.4	5
Monofills	.1	1
Other	.4	5
Total	7.0	100

2. DISPOSAL OPTIONS

a. Landfilling

Co-disposal of sludge with municipal solid waste is a common practice today. Thirty-eight percent of all municipal landfills and almost three-quarters of all large landfills over 1,000 tons per day accept sewage sludge and, presumably, other types of sludges.[4] Landfilling of sludge is typically a joint process with solid waste disposal by commingling the waste. Sludge has also been used as cover material for landfills. The only Federal regulatory requirements for sludge disposal in a sanitary landfill are general landfill requirements for municipal solid waste (MSW) disposal. These regulations include avoiding ground water contamination and substantially reducing disease-causing organisms. The latter requirement is met by composting, heat treatment, digestion, or chemical addition. Another common requirement, but not Federal law, is that the water content of the sludge be reduced so that the sludge does not have the properties of a liquid (i.e., 12 to 15 percent solids). Such a requirement may become law with the pending revisions to the Subtitle D regulations. Many states have been active in developing sludge regulations. In some cases states are banning sludge from landfills.

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[4] Temple, Barker & Sloane, Inc. Analysis of EPA municipal landfill survey data, May 1988.

The constituents of sludges are a potential environmental concern when landfilling. Sewage sludge may contain relatively high levels of heavy metals, which can leach out of the sludge and ultimately the landfill. Water treatment sludges also contain aluminum, calcium, and iron complexes that could leach out. The constituents of industrial sludges depend on the specific industry and process generating the sludge. The degree of potential environmental concern when disposing of sludge will depend on the constituents of the sludge but, more importantly, on the design and operating practices of the landfill and the quantity of sludge being disposed of relative to the other components of the MSW waste stream.

b. Land Application

The second most-common disposal method for sewage sludge and some industrial sludges is land application to use the high organic content and nutrient value of these sludges. (Inorganic industrial and water treatment sludges can be applied to the land but have low value as a soil amendment.)

Sludge is typically applied to the land in one of two ways. The first is to take digested sludge, apply it to a farm or other open land, and then turn the sludge into the soil. The second technique is to compost the sludge, making it a fertilizer and soil amendment product. The resulting material is sold to consumers, nurseries, farmers, golf courses, and others to enhance plant and tree growth. One such product is Nitrohumus, produced jointly by the Los Angeles County Sanitary District and the Kellogg Supply Company.

The greatest problems with land application of sludge are the constituents of the sludge. Again, leachate is an important consideration, as is surface run-off, which could potentially contaminate the ground water or nearby surface waters. Another extremely important consideration is whether or not the area applied with sludge will be used to grow crops for human consumption or animal grazing. When this is the case, strict guidelines at the Federal and State levels apply regarding the constituents of the sludge and the frequency of application. EPA is developing new sludge regulations that will further control this disposal option.

c. Incineration

Sludge incineration is an option for substantially reducing sewage sludge volumes before disposal in a landfill. This approach is practiced at larger-sized sewage treatment plants and industrial facilities. Water treatment sludges are not incinerated because of the low heat content of these sludges. To incinerate sludge, the water content in the sludge is usually reduced to the point where the sludge is autogenous, that is, where the heat content is sufficient to burn the sludge (i.e., 30 to 40 percent solids). This eliminates the need for external fuel and reduces incineration costs. With incineration, disease-causing organisms in the sludge are destroyed during combustion. In some cities, like Indianapolis, sludge is incinerated with municipal solid waste as a co-disposal operation.

The major health and environmental problems associated with sludge incineration are air pollution, caused by combustion, and ash disposal. As mentioned earlier, sludges can contain relatively high levels of heavy metals. During combustion, these metals are not destroyed, but either go up the stack or remain in the ash. Newer incinerators will be required to control air emissions, so the greatest problems with air emissions will come from older sludge incinerators. The ash residue is often sent to the local municipal landfill for disposal where remaining metals have the potential for contaminating leachate formed in the landfill.

d. Ocean Disposal

A relatively smaller portion of our sewage sludge is disposed of in the ocean. This practice has been recognized as unacceptable over the long term, and cities like Boston and New York are working to eliminate this practice. The net result will be even greater sludge volumes directed at the disposal options discussed above.

e. Monofills

Monofills are dedicated sludge disposal landfills. They operate much like a sanitary landfill while receiving only sludge. This option is used infrequently, with only 1 percent of the sludge disposed of in this manner.

3. THE ECONOMICS OF DISPOSAL PRACTICES

The sludge disposal options outlined in this appendix represent a complex set of choices to achieve the lowest cost and the most environmentally sound disposal option. The cost factors to consider in evaluating options, include

- Processing cost
  - --Capital
  - --Operation & Maintenance
- Transportation distance/cost

- Land availability
- Disposal fees
- Revenue potential

For all sludges, the first option considered is onsite disposal, if land is available. However, even when this option is practiced, available space is often used up over time. The next step is to look for a disposal option offsite. This is a very complex decision that must weigh the costs of ultimate disposal, of processing to make the sludge acceptable for that disposal method, and of transportation. The analysis of these costs requires life-cycle costing (see Appendix C), which considers all capital, operating, and maintenance costs for each option. As evidenced by the amount of sludge that is landfilled, landfilling is currently considered one of the more cost-effective disposal options. Other pressures on landfill disposal costs, such as continued losses of landfill capacity and more stringent Federal and State requirements regarding minimum technology, monitoring, and liability insurance, will shift the economics of sludge disposal.

4. PROBLEMS

The greatest problem associated with sludge disposal in landfills relates to the composition of the sludge, its high water content, and the potential for leachate generation that could contaminate ground water. This disposal option creates a potential liability issue should contamination occur and corrective action be required. However, the other options have the same problem and a potentially greater liability in the case of sludge possibly contaminating edible crops.

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4. Sterns, Conrad and Schmidt Engineers, Inc. "Use and Disposal of Municipal Waste Water Sludge," prepared for the U.S. Environmental Protection Agency, Intra-Agency Sludge Task Force, September 1984.

5. Sterns, Conrad & Schmidt Engineers, Inc. Comprehensive Sludge Study, prepared for the U.S. Environmental Protection Agency, December 27, 1978.

6. Temple, Barker & Sloane, Inc. Analysis of U.S. Environmental Protection Agency municipal landfill survey data, May 1988.

TABLE OF CONTENTS

APPENDIX B

E. HOUSEHOLD HAZARDOUS WASTE AND SMALL QUANTITY GENERATORS

Page

1. INTRODUCTION B.E-1

2. HOUSEHOLD HAZARDOUS WASTE (HHW) B.E-1
    a. Definition of HHW B.E-2
    b. Quantities of HHW B.E-2
    c. Sources of Household Hazardous Wastes B.E-3
    d. Management of Household Hazardous Wastes B.E-3
    e. State and Local Activities B.E-9

3. SMALL QUANTITY GENERATORS OF HAZARDOUS WASTE B.E-12

REFERENCES B.E-17

APPENDIX B
OTHER CONTRIBUTORS TO THE WASTE STREAM

E. HOUSEHOLD HAZARDOUS WASTES AND SMALL QUANTITY GENERATORS

1. INTRODUCTION

Municipal solid waste (MSW) is composed of discarded products and materials that contain some hazardous constituents. For example, many household products and materials contain small quantities of hazardous constituents. In addition, small quantities of hazardous materials from commercial businesses may be disposed of with MSW.

In 1984, Congress passed the Hazardous and Solid Waste Amendments (HSWA), which, among other things, directed the U.S. Environmental Protection Agency (EPA) to revise the Subtitle D criteria for solid waste disposal facilities that receive household hazardous waste (HHW) or hazardous waste from small quantity generators (SQG's). Studies by EPA and others have added considerably to our data base since then, but our knowledge is still far from complete.[1,2]

This appendix provides an overview of what is known about HHW and SQG wastes.

2. HOUSEHOLD HAZARDOUS WASTE (HHW)

Studies of HHW have been sponsored by EPA, several states, and other groups. Some of the findings are summarized here.

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[1] U.S. EPA 1986. Subtitle D Study Phase I Report, EPA/530-SW-86-054, U.S. Environmental Protection Agency, October 1986.

[2] U.S. EPA 1988. Report to Congress: Solid Waste Disposal in the United States, Vol. II, Draft Final (Revised), U.S. Environmental Protection Agency, April 15, 1988.

Additional information is available from the EPA, state agencies, several manufacturers, trade associations, and nonprofit groups.

a. Definition of HHW

Household hazardous wastes (HHW) are defined as wastes that meet the technical definition of hazardous wastes in the Resource Conservation and Recovery Act (RCRA) (40 CFR Part 261) and that are generated by households.[3],[4] The characteristics of hazardous waste under this definition include ignitability, corrosivity, reactivity, and extraction procedure (EP) toxicity.[5]

While there is a potential for environmental harm from HHW, good data on the extent of HHW contribution to contamination of incinerator ash, ground or surface water, etc., are not available.

b. Quantities of HHW

While a large number of items in MSW are classified as household hazardous wastes, these wastes appear to be a small percentage of the MSW stream. The Los Angeles County Sanitation District conducted two studies: one estimated that the fraction of HHW in the MSW was less than 0.2 percent by weight, and the second estimated about 0.0015 percent by weight.[6] Surveys conducted by the University of Arizona in New Orleans, Louisiana, and in Marin County, California, found that HHW was approximately

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[3] U.S. EPA 1986.

[4] U.S. EPA 1988.

[5] U.S. Environmental Protection Agency. "Regulations for Identifying Hazardous Waste," 40 CFR Part 261.

[6] U.S. EPA 1986.

0.35 to 0.40 percent by weight of MSW.’

c. Sources of Household Hazardous Wastes

Most of the substances classified as HHW are residues of products. A few, like batteries, are discarded in their original form. A representative listing of HHW is shown in Table B.E-1.

The substances in Table B.E-1 are hazardous because they meet one or more of the Part 261 criteria: ignitability (e.g., solvents); corrosivity (e.g., oven cleaners); reactivity (e.g., pool chemicals); or EP toxicity (e.g., pesticides).

Used oil and batteries are often classified as HHW. Because of their significance, these products are discussed in other appendices to this report.

d. Management of Household Hazardous Wastes

Household hazardous wastes are generally disposed of in the same manner as other MSW--they are collected along with the other wastes and are landfilled or incinerated with no special treatment. In other words, management of HHW has been by the methods at the bottom of the solid waste management hierarchy. As awareness of potential problems caused by HHW has grown, more attention has been given to methods at the top of the hierarchy: reducing, reusing, and recycling. However, most HHW will continue to be landfilled for the foreseeable future.

(1) Landfilling

Disposal of HHW in a well-designed and properly managed landfill will significantly reduce the risk of environmental

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’U.S. EPA 1986.

TABLE B.E-1

REPRESENTATIVE HOUSEHOLD HAZARDOUS WASTES

Category	Examples
Automotive, Boat, Equipment Maintenance	Antifreeze
	Auto degreasers
	Automotive rubbing compounds
	Batteries
	Brake fluid
	Carburetor cleaners
	Gasoline
	Lubricating oil
	Motor fuel additive
	Radiator flushes
	Rust inhibitor
	Transmission fluid
	Undercoatings
	Windshield washer fluid
Home and Household Maintenance	Air cleaners
	Bleach
	Coffee pot cleaners
	Concrete cleaner
	Deck and patio cleaners
	Degreasers
	Deodorizers
	Dishwasher detergent
	Disinfectants
	Drain cleaner
	Fire extinguishers
	Fireplace cleaners
	Floor cleaners
	Floor waxes
	Fluorescent lamp ballast
	Furniture polish
	Household cleaner
	Laundry products
	Metal polish
	Mothballs
	Oven cleaners
	Polishes
	Pool chemicals
	Rug cleaners
	Septic tank cleaners
	Shoe care products
	Smoke detectors
	Spot removers
	Toilet bowl cleaner
	Window cleaners

Table E-1 (continued)

Category	Examples
Paint Products	Brush cleaners Paint remover Paint thinner Paints Shellac Solvents Varnishes Wood preservative Wood stains
Repair and Remodeling	Adhesives and glues Caulking compounds Joint compounds Roof coatings Sealants Stove lining White lead putties Wood putty
Hobby, Pet, and Recreation Products	Acids Aerosols Artist's paint Bottled gas Chemistry sets Dyes Flea powder Glazes Glues and cements Solvents and thinners Inks Paints Photography chemicals Waxes Wood stains
Personal Care Products	Denture cleaners Nail polish and remover Rubbing alcohol Thermometers

Table E-1 (continued)

Category	Examples
Lawn and Garden Products	Pesticides (EP toxic or listed) Herbicides (EP toxic or listed) Fungicides (Listed)

Source: Washington State Department of Energy, Tufts University, EPA's Subtitle D Report, and EPA's Report to Congress.

damage. Unfortunately, many currently operating landfills do not meet Subtitle D standards, so it is important to look at other management alternatives.

(2) Community Programs

Community programs to collect HHW for proper disposal have become increasingly popular. EPA estimates that these programs have increased from two programs in one state in 1981 to 849 programs in 41 states recently.[8] Most of these are 1-day events, but more permanent collection programs are being established. A few communities have encouraged reuse of HHW, such as paints, by facilitating exchange of materials among residents.

The publicity that goes with a well-managed HHW collection program helps to educate citizens about HHW and how to handle these wastes safely.

Several other countries (e.g., Austria, Denmark, the Netherlands, and the United Kingdom) have practiced separate collection of HHW.[9]

There are some impediments to community HHW collection programs. Participation is usually low, the amounts collected are usually small, and the cost per pound collected is thus high. HHW grant recipients in one state reported costs ranging from about $1 per pound collected to $6 per pound collected.

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[8] Carra, Joseph. "Municipal Solid Waste Management in the United States: An Overview," presented at the Municipal Solid Waste Source Reduction and Recycling Conference, Hot Springs, Virginia, March 23, 1988.

[9] Forester, William S., and John H. Skinner. International Perspectives on Hazardous Waste Management, Academic Press, 1987.

Also, the permits issued to hazardous waste disposal facilities may prevent the acceptance of unidentified household wastes. Liability issues have also been a problem in some areas. Some State regulations that are more stringent than the Federal may limit disposal of collected HHW.

(3) Other Educational Programs

Public education on proper use and disposal of HHW is a long-term, but essential, management method. Some State and local governments, manufacturers of HHW, trade associations, and nonprofit organizations have undertaken educational programs. The League of Women Voters has been particularly active in these programs.[10]

(4) Source Reduction

Source reduction of HHW is just beginning to receive attention in the United States; for example, some educational programs emphasize the selection of nonhazardous alternatives to HHW. Recent gains have recently been noted by some U.S. battery manufacturers in reducing the quantity of mercury used in the dry cell battery. Some other countries have taken steps to reduce HHW. In Japan, the manufacturers of dry cell batteries containing mercury have undertaken a program to reduce the amount of mercury in the cells.[11] The Governments of Denmark and Austria are considering requiring the labeling of products containing hazardous materials.[12] The idea would be to encourage residents to separate the materials from other wastes, as well as to give an incentive to manufacturers to use nonhazardous products. Some states in this country are reported to be considering labeling also.

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[10] League of Women Voters of Massachusetts. "Household Hazardous Wastes: Everyone's Problem," undated.

[11] Forester.

[12] Forester.

e. State and Local Activities

As the issue of HHW has received increasing attention, many State and local governments have considered or implemented programs. These generally are collection and/or education activities. In this appendix, it is possible to mention only a few examples.

(1) State Activities

Several states--including California, Connecticut, Minnesota, New Jersey, Rhode Island, and Vermont--have sponsored studies on HHW and related issues. Some states have considered product warning labels but have not enacted regulations at this time.

States have also provided assistance for local collection programs and educational activities. Michigan provided funds for HHW collection programs in 10 communities; county health departments typically implemented the programs. Florida has collection programs that include agricultural and SQG wastes. Connecticut, Massachusetts, Minnesota, Rhode Island, and Vermont, are other examples of states that have provided assistance to local collection programs.[13] Iowa has enacted a State education program.

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[13] SCS Engineers. A Survey of Household Hazardous Wastes and Related Collection Program, EPA/530-SW-86-038, U.S. Environmental Protection Agency, October 1986.

(2) Local Activities

As noted above, there have been many HHW collection programs in the United States in the past few years. While most of these have been 1-day collection activities (sometimes more than once a year), some communities have established permanent collection points for HHW. Santa Barbara County and Orange County, California, are two examples of efforts to establish permanent HHW collection sites. Permanent collection centers in San Bernardino County, California, are described briefly in this section. In addition, a brief description of a 1-day collection in Seattle, Washington, is included as an example program.

San Bernardino County, California.[14,15] The County has sited two collection centers, one at a fire station and one at the County Agricultural Commissioner's Office. The centers provide safe storage for the HHW brought in. The Department of Health Services provides training for collection center personnel. However, fire fighters have training in handling hazardous materials, and they were already receiving calls from the public about disposing of HHW. Likewise, the Agricultural Commissioner's Office was already involved in distributing pesticides and receiving back unused pesticides.

Education and publicity about the program include news releases, public service announcements on radio and TV, flyers and brochures, articles in newsletters, and staff presentations at community meetings. Local landfill operators also refer residents to the collection centers.

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[14] Roberts, R. L., and S. Van Stockum. "San Bernardino County Pilot Project: Household Hazardous Waste Collection Centers," February 1987.

[15] Roberts, R. L., and S. Van Stockum. "Program for Management of Small Quantities of Hazardous Waste," Final Report, December 12, 1985.

In addition to the collection centers, the County has held two 1-day Toxics Roundups.

The program has been funded by State grants (75 percent) and by the County (25 percent). In an application for a 1986/1987 grant, County DEH officials estimated that 14,000 gallons of HHW would be diverted from sewers or landfills during the year. This was estimated to be 2.5 percent of HHW entering the landfill.

Seattle, Washington.[14] On May 30, 1987, a collection day in Seattle attracted participation from 4,091 households at four sites, where 117 tons of HHW were collected. Participants included 14 governmental units that contributed staff and funds, another 12 governmental units that contributed publicity, 4 chemical companies that donated labor and provided discounts for other activities, and the Metrocenter YMCA, which coordinated the effort.

Publicity for the event included TV public service announcements, news releases, media events, and mailings. Pre- and post-event surveys showed an increase of 15 percentage points among people who could identify HHW.

To pay costs not covered by donations, each participating governmental agency was assessed 7 cents per capita for the disposal of the wastes.

There have been previous collection events in the Seattle area. The Health Department accepts hazardous materials by appointment at five locations. One chemical company accepts small quantities of HHW from the public at no cost. Three cities in the area have previously held collection programs.

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[14] Conlin, Richard. Report on 1-day, multiple-site collections, undated.

3. SMALL QUANTITY GENERATORS OF HAZARDOUS WASTE

National data on small quantity generators (SQG's) of hazardous waste are contained primarily in a report prepared for the U.S. Environmental Protection Agency in 1985.[17] The report summarizes the results of a survey of small quantity generators of hazardous waste; the survey was conducted between January 1983 and October 1984.

The report defines SQG's as those business establishments generating under 1,000 kilograms per month. Within this group are those generating between 100 kilograms and 1,000 kilograms per month, defined as SQG's, and those generating less than 100 kilograms per month, defined as very small quantity generators (VSQG's). The VSQG's are, currently, the only business establishments generating hazardous wastes that are excluded from the Subtitle C requirements under RCRA. Thus, VSQG's are the focus on the discussion presented here.

The number of VSQG's in the United States is estimated at between 450,000 and 500,000. These establishments represent 75 percent of all SQG's and 73 percent of all business establishments generating hazardous waste.

The national survey report cited above indicated the following distribution of VSQG's by type of industry:

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[17] Abt Associates, Inc. National Small Quantity Generator Survey, U.S. EPA Contract No. 68-01-6892, U.S. Environmental Protection Agency, 1985.

Industry Group	Percent of VSQG's
Vehicle Maintenance	48
Construction	13
Other Nonmanufacturing	22
Metal Manufacturing	8
Other Manufacturing	9
TOTAL	100

Industries with significant numbers of VSQG's in the other nonmanufacturing group include:

- Laundries
- Printing/Ceramics
- Pesticide-Application Services
- Photography
- Analytical and Clinical Laboratories
- Wholesale and Retail Establishments
- Educational and Vocational Establishments
- Other Services (e.g., cleaning/maintenance)

Of the other manufacturing industries, none were particularly significant in terms of the number of VSQG's.

It should be noted that the distribution of VSQG;s contained in the national survey report does not account for so-called "incidental generator groups"; the VSQG's within these industries are estimated to be at least 15 percent of all VSQG's. Addition of these VSQG's to the industry group categories listed above would increase the other manufacturing and other nonmanufacturing percentages with corresponding decreases in the remaining industry groups.

The total quantity of hazardous waste generated by VSQG's is estimated at about 190,000 metric tons per year. This is about 20 percent of that generated by all SQG's and less than 0.1

percent of hazardous waste from all business establishments.

The major hazardous waste streams generated by VSQG's, as indicated from the national survey, are the following:

Waste Stream Stream[18]	Percentage (by weight) of VSQG Waste
Used Lead-Acid Batteries	60.5
Spent Solvents	18.1
Dry Cleaning Filtration Residues	4.8
Photographic Wastes	4.1
Waste Formaldehyde	3.2
Strong Acids or Alkalies	1.8
Ignitable Paint Wastes	1.7
Empty Pesticide Containers	1.2
Pesticide Solutions	1.0
Solutions/Sludges Containing Silver	0.9
Other Ignitable Wastes	0.8
TOTAL	98.1

Again, it must be noted that waste streams from a number of industries having VSQG's were not included in the quantities used to develop these figures. Thus, the relative significance of the waste streams listed above may be somewhat different than indicated from the available data.

Regardless of the potential changes that might be made in the above list, the largest hazardous waste stream from VSQG's is clearly used lead-acid batteries. Spent solvents is the next largest category; all the other listed waste streams are small in comparison to these first two.

The national survey report did not distinguish between SQG's and VSQG's with respect to the numbers of each using offsite versus onsite hazardous waste management. For all SQG's surveyed, 79 percent used offsite waste management alone or in combination with onsite management. The quantity of hazardous waste these generators shipped offsite accounted for 84 percent of the total they generated.

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[18] Abt Associates, Inc.

The national survey report did distinguish between SQG's and VSQG's with respect to hazardous waste management practices. Distribution of VSQG's by waste management practice was indicated in approximately the following proportions for offsite and onsite managed hazardous waste:

Offsite Management Practices of VSQG's

Waste Management Practice	Percent
Recycling	61
Solid Waste Landfill	17
Unknown	22
TOTAL	100

Management Practices of of VSQG's

Waste Management Practice	Percent
Recycling	23
Sewer System	47
Treatment	20
Unknown	10
TOTAL	100

Several VSQG's use a combination of both onsite and offsite waste management techniques, and some of their wastes are subjected to both onsite and offsite management. For example, some wastes are treated onsite before being sent to an offsite landfill. In other cases, a VSQG may manage one of its wastes onsite and another offsite. The VSQG's using both onsite and offsite hazardous waste management are included in both the onsite and offsite distributions shown above.

The data available are not sufficient to determine the ultimate disposition of all the hazardous waste generated by VSQG's. However, the majority of these wastes are judged to have been recycled at the time of the national survey--January 1983 to October 1984. As previously indicated, lead-acid batteries from vehicles constitute over half of the total quantity of hazardous wastes estimated from VSQG's, and lead-acid batteries are recycled at relatively high rates. (See Appendix A.)

While recycling may still be the dominant offsite management practice for VSQG hazardous wastes, landfills and sewer systems are also used significantly. In some instances, the wastes are treated before their ultimate disposition by another means.

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APPENDIX B

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8. Sterns, Conrad & Schmidt Engineers, Inc. A Survey of Household Hazardous Wastes and Related Collection Programs, EPA/530-SW-86-038, U.S. Environmental Protection Agency, October 1986.

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12. Washington State Department of Ecology Solid and Hazardous Waste Program and Center for Environmental Management; Tufts University. "Hazardous Household Substances List," Draft, June 1987.

TABLE OF CONTENTS

APPENDIX B

F. USED OIL

Page

1. BACKGROUND B.F-1
   - a. Contaminants in Used Oil B.F-1
   - b. Used Oil in Municipal Solid Waste B.F-3

2. CURRENT FEDERAL ACTIVITIES B.F-4
   - a. Statutes B.F-4
   - b. Current Initiatives B.F-5

3. CURRENT MANAGEMENT PRACTICES B.F-7
   - a. Collection B.F-7
   - b. Re-refining B.F-8
   - c. Processing B.F-9
   - d. Burning Used Oil as Fuel B.F-10

4. STATE PROGRAMS B.F-10

REFERENCES B.F-13

APPENDIX B

OTHER CONTRIBUTORS TO THE WASTE STREAM

F. USED OIL

1. BACKGROUND

Lubricating oils are used to reduce friction and wear by interposing a film of material between rubbing surfaces. These oils are compounds of a refined oil or synthetic oil basestock and an additive package tailored to meet the requirements of the intended enduse of the oils.[1]

Lubricating oils have many applications. Automotive lubricating oils include engine oils, hydraulic fluids, and gear oils. Industrial lubricating oils include general lubricants (e.g., hydraulic, circulating, turbine, and gear oils); engine oils; metal-working oils (e.g., rolling, cutting, grinding, and quenching oils); and electrical rubber, spray, ink, and other process oils. Lubricating oils also are used in railroad, marine, and aviation engines.[2]

a. Contaminants in Used Oil

During service, automotive oils are contaminated by the breakdown of the additive package and by other sources such as dirt, rust, metal particles from engine wear, gasoline from incomplete combustion, and so forth. Used automotive oil can also be contaminated if it is mixed with other products such as solvents or used industrial oils. Industrial used oils can pick up many hazardous contaminants as they are used.

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[1] U.S. EPA 1987a. "Guideline for Re-refined Oil Content in Oil Procured by the Federal Government; Proposed Rule," U.S. Environmental Protection Agency, 40 CFR Part 252, Federal Register, October 19, 1987.

[2] U.S. EPA 1987a.

Results of a used-oil testing program by the U.S. Environmental Protection Agency (EPA) are summarized in Table B.F-1.

TABLE B.F-1

CONCENTRATION OF POTENTIAL HAZARDOUS CONSTITUENTS IN USED OIL

Constituents	Median Concentration (ppm)
Metals	
Arsenic	5
Barium	48
Cadmium	3
Chromium	6.5
Lead	240
Zinc	480
Chlorinated Solvents	
Dichlorodifluoromethane	20
Trichlorotrifluoroethane	160
1,1,1-Trichloroethane	200
Trichloroethylene	100
Tetrachloroethylene	106
Total Chlorine	1,600
Other Organics	
Benzene	20
Toluene	380
Xylenes	550
Benzo(a)anthracene	12
Benzo(a)pyrene	10
Naphthalene	330
Polychlorinated Biphenyls (PCB's)	5

Source: Franklin Associates, Ltd. Composition and Management of Used Oil Generated in the United States, prepared for the U.S. Environmental Protection Agency, September 1984.

Since these tests were made, use of lead as a gasoline additive has decreased because of the phase-out of its use.

b. Used Oil in Municipal Solid Waste

The background documents for EPA's regulatory analysis[3] includes an analysis of the flow of used oil in the United States in 1983. It was established that over 2 billion gallons of lubricating oil were sold that year. About 1.2 billion gallons became used oil; the rest was lost in use.

As will be discussed later, an estimated two-thirds of used oil is recycled by several methods, including burning.[4] The used-oil background document[5] estimated that 165 million galons were disposed of with municipal solid waste (MSW) by landfilling or incineration and 241 million gallons were simply dumped.

The most likely source of used oil in MSW is the automotive oil generated by oil changing do-it-yourselfers (DIY's) and very small quantity generators (VSQG's)[6] such as small industry automboile fleets and service stations. The background report estimated DIY's disposed of 41 million gallons of used oil in MSW in 1983, and dumped 118 million gallons.

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[3] Franklin Associates, Ltd. Composition and Management of Used Oil Generated in the United States, prepared for the U.S. Environmental Protection Agency, September 1984.

[4] California DHS Symposium. "EPA's Evolving Used Oil Regulatory Strategy," April 1988.

[5] Franklin Associates, Ltd.

[6] See Appendix B.E for definitions of this term.

2. CURRENT FEDERAL ACTIVITIES[7]

a. Statutes

Recognizing the problems and concerns associated with used oil, Congress enacted legislation in 1980 and 1984 amending the Resource Conservation and Recovery Act (RCRA) that established specific goals and provisions for regulating used oil. The Used Oil Recycling Act of 1980 (UORA) mandated that EPA promulgate regulations establishing standards to protect the public health and the environment from risks posed by improper management of used oil. The statute also provided that "...such regulations...not discourage the recovery or recycling of used oil."

The Hazardous and Solid Waste Amendments of 1984 (HSWA) established additional mandates and provided for additional constraints on regulation of recycled used oil consistent with Congress' earlier stated goals. These amendments establish special provisions within Subtitle C (Hazardous Waste Management) of RCRA that authorize EPA to develop a separate regulatory framework for recycled used oil regardless of whether it is listed or identified as a hazardous waste.

In the Superfund Amendments and Reauthorization Act of 1986 (SARA), Congress also limited the liability of certain facilities (e.g., service stations) that provide collection centers for used oil generated by DIY's. This provision will be applicable when final facility management standards are issued.

On November 19, 1986 (51 FR 41900), after further evaluation, the Agency published a final determination not to list used oil bound for recycling as a hazardous waste under RCRA, and then it set out a strategy to decide how to control used oil bound for disposal. The proposed management standards and certain other initiatives (e.g., burning controls) were deferred pending the outcome of the decision on disposal controls. Since then, the Agency has evaluated a number of options and has determined that listing for disposal only under RCRA would be preferable to use of the statutory authorities in the Toxic Substances Control Act (TSCA), Section 6, for controlling the disposal of used oil.

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[7] This section is taken from the reference by California DHS Symposium.

b. Current Initiatives

EPA's current strategy to minimize the potential risks posed by the improper management of used oil and to encourage recycling involves using a combination of regulatory and nonregulatory programs. These initiatives are summarized below:

- EPA is developing an education program to promote the voluntary recycling of used oil from DIY's. Only 10 percent of DIY oil is presently recycled, as compared to 80 percent of industrial oil. This program will, among other things, serve as a clearinghouse for information to State and local governments about recycling, and to other groups interested in recycling.

- The Agency plans to issue management standards to modify its existing used-oil regulations and to strengthen the prohibition on mixing used oil and hazardous waste. This mixing is a major contributor to total risk posed by used oil.

- EPA will place additional management controls on all used oil, including recycled used oil, through its Underground Storage Tanks program.

- After close examination, EPA has determined that used oil disposal (where used oil is unmixed with hazardous waste and does not exhibit a hazardous waste characteristic) should be controlled by a risk-based concentration-driven listing. Recycling and disposal of used oil mixed with hazardous waste is already controlled under existing hazardous waste regulations. Disposal of used oil that exhibits a hazardous waste characteristic is also controlled under the hazardous waste rules, although recycled used-oil fuel that exhibits a characteristic is exempt. However, a concentration-based listing cannot be promulgated until EPA develops a risk assessment model for oily wastes. EPA will also gather additional data on the composition of used oil for this listing.

- EPA will propose listings for residuals from used-oil recycling. These listings are also contingent on the development of the oily waste fate and transport model.

- EPA, through its Office of Toxic Substances, will act on a proposal to relax restrictions on used oil containing detectable concentrations of polychlorinated biphenyls (PCB's) up to 49 parts per million to allow burning in units now eligible to burn "off spec" used oil.

Because assessing the need for a comprehensive set of management standards for recycled used oil will largely depend on the outcome of the listing efforts, initiatives in the area of management standards for generators, transporters, and recyclers will be limited to those discussed above. Efforts to develop additional burning regulations are on hold.

3. CURRENT MANAGEMENT PRACTICES

Used oil is generated from automotive and industrial sources. It may be collected for processing or re-refining. The major enduse of recovered oil is burning as fuel. (The used oil may or may not be processed or re-refined before it is burned.) Other uses for recycled used oil include use in road oiling, as lubricating oil, as cutting and honing oils, and as asphalt extenders. (Many states have restricted the use of used oil in road oilings because of environmental hazards.)

a. Collection

In the past, used oil for recycling has generally been collected by independent collectors from generators such as gas stations, car dealers, and so forth. In an effort to reach DIY's, who typically have dumped their used oil, EPA and some states are encouraging new collection systems.[8,9] These include the following:

- Taking the used oil to a business with an oil collection tank (e.g., a service station)
- Having a dedicated collection site
- Using curbside collection
- Establishing special collection days when a drop-off site is designated

EPA has started a newsletter and other educational activities for DIY's.

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[8] Biocycle. "Oil Recyclers Target Do-it-yourselfers," Biocycle, April 1988.

[9] U.S. EPA 1988. Used Oil Recycling (newsletter), U.S. Environmental Protection Agency, Office of Solid Waste, March 1988.

b. Re-refining[19]

The American re-refining industry dates back to the early 1900's. At that time, re-refining was a relatively simple process of heating, settling, and seprating by centrifugal force. The Armed Forces used re-refined oils for aircraft engines during both World Ward and thereafter. Commercial airlines began using it in 1932. However, the development of jet engines, which require more complex engine oils, led to declining use of re-refined oils in aircraft.

At the same time as the aircraft market was declining, the automotive engine market was growing. By 1960, more than 150 companies were producing 300 million gallons of re-refined oils annually. As with the aircraft engines, the development of high-performance automobile engines, which require complex lubricating oils, created problems for re-refiners. The predominant re-refining technology was acid/clay, which was not very effective in removing many of the new, more sophisticated addities and other contaminants in the used oila nd which generated a large amount of hazardous waste. Economic and regulatory factors, combined with the technological problems caused by advances in additive technology, forced the industry into decline.

During the late 1970's and early 1980's, new re-refining technologies, which are capable of economically and effectively removing the contaminants from used oil, were developed and put into use commercially. The majority of American re-refiners use a modern technology, generally one of the vacuum distillation processes. However, re-refiners currently apply only 5 percent of the lubricating oils in the United States.

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[19] Much of the information in this section is from the reference by U.S. EPA on re-refined oil.

According to the National Bureau of Standards (NBS), there has been sufficient engine and field testing of re-refined engine oils to demonstrate that these oils can meet the prescribed test limits, are substantially equivalent to virgin oils, and, for some parameters, perform better than virgin oils. NBS has found that there are measurable differences between virgin oils and some re-refined oils in some characteristics and in some test results. These differences include levels of oxyacids, viscosity index improvers, chlorine, and additive/wear metals, as well as total acid number and saponification number. However, these differences do not have any apparent effects on engine performance.

On October 19, 1987, EPA published a proposed guideline for re-refined oil content in oil procured by the Federal Government.[11]

c. Processing

Minor processors of used oil now use simple technology such as in-line filtering and gravity settling, with or without added heat. The processed oil is marketed for direct fuel use, for blending with virgin fuel oil, for nonfuel industrial uses, for road oiling, or for further processing by a major processor. The oil may also be used for in-house heating.[12]

Major processors use more sophisticated technology, such as tertiary treatment devices. Distillation towers, filter screens, centrifuges, agitators, and blending devices may be used. The markets for the processed oil include direct fuel sales, sales to virgin fuel oil dealers, nonfuel industrial uses, and road oiling. The oil is often used for in-house heating.[13]

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[11] U.S. EPA 1988.

[12] Franklin Associates, Ltd.

d. Burning Used Oil as Fuel

Burning was the largest enduse category for used oil in 1983. Most used oil that is burned has been processed to at least some degree. Used oil is burned in various sizes and types of boilers, in small space heaters, in incinerators, in asphalt plants, in cement kilns, and in diesel engines. Blending with virgin oil is fairly common.[14]

4. STATE PROGRAMS

In 1987, EPA's Office of Solid Waste surveyed the United States to determine the extent of each state's used oil regulations. The results are summarized in Table B.F-2.[15]

Programs aimed at DIY oil changers are of special interest with respect to management of MSW, since DIY's tend to dispose of used oil in the MSW or to dump it.

One state (Alabama) and a number of local communities have been promoting curbside collection of used oil.[16] In Alabama, Project ROSE (Recycled Oil Saves Energy) has been active.[17]

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[13] Franklin Associates, Ltd.

[14] Franklin Associates, Ltd.

[15] U.S. EPA 1987b. "State Regulations/Programs for Used Oil," U.S. Environmental Protection Agency, Office of Solid Waste, December 1987.

[16] Versar, Inc. Review of Curbside Used Oil Recycling Programs in the United States, U.S. Environmental Protection Agency, Office of Solid Waste, April 1988.

[17] The section on Project ROSE is from U.S. EPA 1988 (see References).

Project ROSE receives office space and support personnel from the University of Alabama. Otherwise, it is funded through the Alabama Department of Economics and Community Affairs. The project has two full-time staff members--the Project Coordinator and the Promotional Assistant. The State grants monies to pay for various educational materials such as brochures, flyers, information packets, and a slide show that is distributed on request. Project ROSE's greatest assets are its many volunteers who are active in every part of the program.

Project ROSE communicates its message through the media, schools, special events, and civic and volunteer organizations. For example, the project airs biannual public service announcements on every radio and television station in the area, publishes press releases in local papers and magazines, produces and distributes brochures, and mails a quarterly newsletter to 1,200 subscribers. In addition, the State's telephone service and power company include information about Project ROSE with their bills at least once a year.

Project ROSE assists communities and cities by offering several recycling options, which allow them to design programs to meet their specific needs. The three options currently being used are curbside collection, collection centers, and drum placement. Because much of Alabama is rural, collection centers, in the form of service station collection, are the most widely used system. Several larger cities provide curbside collection of used oil. In Tuscaloosa, the garbage trucks are fitted with racks to carry the used oil. The State has eight Program Center locations where volunteers help promote, operate, and maintain the program in their area.

TABLE B.F-2

STATE REGULATIONS/PROGRAMS FOR USED OIL

Regulatory Summary	Total for All States
State maintains equivalent Federal EPA used-oil poilicies and regulations	20
State maintains policies or regulations that are more stringent than Federal EPA's	12
State has standards and regulations that are less stringent than Federal EPA's	20
State regulates used oil as a hazardous waste/ hazardous substance	9
Do-it-yourselfer (DIY) programs present and active	27
Evidence of current and local recycling programs	32
Management requirements present	
Generators	15
Marketers	13
Burners	19
Transporters	15
Recyclers	15
Manifest/Recordkeeping requirements	19
Storage requirements present	
Generators	13
Marketers	9
Burners	13
Transporters	15
Recyclers	15
Exemptions	
Small quantity generators (SQG's)	19
Other	6
Specific regulations/restrictions	
Mixing with hazardous waste	16
Road oiling	21
Blending	10
Retailer (virgin oil) requirements	
Service stations required to accept DIY oil	4
Other requirements	6
Parallel regulatory restrictions	
Municipal landfill regulations	14
Sewer regulations	12

Source: U.S. EPA 1987b. "State Regulations/Programs for Used Oil," U.S. Environmental Protection Agency, Office of Solid Waste, December 1987.

REFERENCES

APPENDIX B

F. USED OIL

1. Biocycle. "Oil Recyclers Target Do-it-yourselfers," *Biocycle*, April 1988.

2. California DHS Symposium. "EPA's Evolving Used Oil Regulatory Strategy," April 1988.

3. Franklin Associates, Ltd. *Composition and Management of Used Oil Generated in the United States*, prepared for the U.S. Environmental Protection Agency, September 1984.

4. U.S. EPA 1987a. "Guideline for Re-refined Oil Content in Oil Procured by the Federal Government; Proposed Rule," U.S. Environmental Protection Agency, 40 CFR Part 252, *Federal Register*, October 19, 1987.

5. U.S. EPA 1987b. "State Regulations/Programs for Used Oil," U.S. Environmental Protection Agency, Office of Solid Waste, December 1987.

6. U.S. EPA 1988. *Used Oil Recycling* (newsletter), U.S. Environmental Protection Agency, March 1988.

7. Versar, Inc. *Review of Curbside Used Oil Recycling Programs in the United States*, prepared for the U.S. Environmental Protection Agency, Office of Solid Waste, April 1988.

TABLE OF CONTENTS

APPENDIX B

G. INFECTIOUS WASTE

Page

1. INTRODUCTION B.G-1

2. AVAILABILITY OF DATA B.G-3

APPENDIX B

OTHER CONTRIBUTORS TO THE WASTE STREAM

G. INFECTIOUS WASTE

1. INTRODUCTION

On June 2, 1988, the U.S. Environmental Protection Agency (the Agency or EPA) published in the Federal Register a Notice of data availability and request for comment on infectious waste management. The purpose of the Notice was to make Agency information on the safe management of infectious wastes available to the public and to solicit public comment on a number of issues pertaining to infectious waste and the possible need for further governmental action. The Agency believes that the proper management of infectious waste is crucial to ensure that any potential hazards to the public and to individual workers are avoided. The following information in this appendix is an excerpt from the Federal Register of June 2, 1988. For additional information, contact Denise Zabinski, Office of Solid Waste (WH-562B), U.S. EPA, 401 M Street, S.W., Washington, D.C. 20460, (202)382-7458.

By way of background, on December 18, 1978, the Agency proposed regulations under the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (RCRA) of 1976 (Pub. L. 94-580 of October 21, 1976), which would classify certain infectious wastes as hazardous waste. These wastes included infectious waste generated by certain departments in health care facilities and veterinary hospitals, by laboratories handling etiologic agents, and by sewage treatment facilities, unless these wastes were sterilized or incinerated in accordance with specified methods. (See 43 FR 58946, 58956, of December 18, 1978.)

The Agency proposed to list these wastes as hazardous because the Agency believed at that time that if they were improperly managed, they could pose a substantial hazard to human health and the environment. It should also be noted that the statutory definition of hazardous waste specifically cited infectiousness as one of the properties that the Agency should consider in its evaluation in defining wastes as hazardous; see section 1004(5), where it states "the term hazardous waste means a solid waste, or combination of solid wastes, which because of its quality, concentration, or physical, chemical, or infectious characteristics, may...." Significant comments were received on the proposal; based upon these comments infectious waste was not identified or listed as a hazardous waste when the regulations were made final on May 19, 1980. (See 45 FR 33087.) Instead, the Agency initiated several activities to collect information and assess the problems posed by infectious waste management and disposal. This information was then used by the Agency to develop a draft guidance document in 1982 (on which comment was solicited) on infectious waste management. EPA then brought in professionals from the health care industry to provide additional information in preparing a final guidance document, which was published in 1986. This document outlined a prescriptive program for the management of infectious waste. (See "EPA Guide for Infectious Waste Management," described in detail below.) Additional guidance on the management of infectious waste has also been provided. (See "Hospital Waste Combustion Study," described below, for a more detailed discussion.)

In addition to publishing guidance in May 1986, the Agency has taken an active role in training health care professionals regarding the responsible management of infectious waste. Staff from the Agency has participated as faculty or professional experts at symposia sponsored by the American Hospital Association and the American Society for Hospital Engineering.

Furthermore, in November of 1987, as a result of several isolated incidents of improper management and disposal of infectious wastes and growing public concern about the potential threat of infectious waste to human health and the environment, the Agency called together a panel of experts to discuss the definition of, proper management of, and risks posed by infectious wastes.

The recent Notice of data availability and request for public comment was a further effort to (1) make available to the public and those persons responsible for managing infectious waste the EPA guidance manual, and (2) solicit comment on issues of concern regarding the proper management of infectious waste. The Agency believes that the proper management of infectious wastes can significantly reduce the risks associated with these wastes. The Agency, with this Notice, will reevaluate and assess the problems posed by infectious wastes to determine if further Federal governmental action is necessary.

2. AVAILABILITY OF DATA

As already indicated, the Agency has not promulgated regulations controlling the management of infectious waste; instead, a number of guidance documents have been prepared to assist the states and other interested in the management of infectious waste. These documents are (1) "EPA Guide for Infectious Waste Management", U.S. EPA, Office of Solid Waste and Emergency Response, EPA/530-SW-86-014, May 1986; and (2) "Hospital Waste Combustion Study, Data Gathering Phase, Final Draft Report", prepared by Radian Corporation, Research Triangle Park, N.C., for U.S. EPA, Office of Air Quality Planing and Standards, EPA Contract No. 68-02-4330, October 1987. Each of these documents is included in the RCRA public docket, at the address listed above. The following is a brief description of each document and includes further information on how the public can obtain copies:

(1) The "EPA Guide for Infectious Waste Management" outlines the EPA perspective on environmentally acceptable techniques for managing infectious wastes. Topics covered include a definition of infectious waste, the various categories of waste included under the definition, and recommended practices for packaging, transportation, treatment, storage, and disposal of these wastes. In particular, the document discusses various types of treatment alternatives and describes the suggested treatment methods for each waste category. The document is intended to provide guidance to persons responsible for infectious waste management. State and local regulatory agencies also will find this manual useful as resource material. Copies are available as Publication No. PB86-199130 from the National Technical Information Service (NTIS), Port Royal Road, Springfield, Virginia, (703) 478-4650. This document is also available in the RCRA public docket.

(2) The "Hospital Waste Combustion Study," October 1987, summarized readily available information on the hospital waste combustion industry including waste characterization, industry technology, multipollutant air emissions data, emission control technologies, current regulation and control strategies, and hospital waste combustor population characteristics, including suggested model plant parameters for use in exposure modeling. The study was initiated by EPA's Office of Air Quality Planning and Standards in response to increasing concerns over the potential public health impacts from the disposal of hospital wastes, including incineration and other methods of disposal. This document is available in the RCRA public docket.

In addition to the development of these documents, the

Agency held a meeting in November 1987 to discuss these issues pertaining to infectious waste management. The primary purpose of this meeting was to discuss and evaluate the nature and extent of the risks to human health and the environment posed by wastes that contain infectious materials. The meeting was held in response to growing concerns about infectious waste management and to assist EPA in determining whether the Agency should undertake any additional action under the Resource Conservation and Recovery Act. Infectious waste issues were discussed by a group of experts representing health care professionals and practitioners from Government, academia, industry, and professional and trade associations called together by the EPA. The proceedings of this meeting have been made available to the public. (See "Report on the Proceedings of the EPA Infectious Waste Management Meeting, November 12, 1987, EPA Headquarters, Washington, D.C.," available in the RCRA public docket).

The Agency also has examined a recent survey entitled "State Infectious Waste Regulatory Programs," assembled for the Council of State Governments, which summarizes the current status of state infectious waste regulations. This document is available from the Council of State Governments.

The Agency requested comments on the following issues concerning exemptions from infectious waste controls: Should any generators of infectious waste be exempted from management controls? Do small health care operations pose less risk because of the amount of waste they produce? If no generators are exempted, how many generators would be subject to infectious waste controls?

The Notice identified specific issues in five categories and solicited public comment on those issues:

- Definition of Infectious Waste
- Nature of the Problem Posed by Infectious Waste
- EPA's Role in Infectious Waste Management
- Tracking System for Infectious Waste
- Exemptions From an Infectious Waste Control Program

The Agency specifically requested comments on all of the issues included in the Notice. Comments on additional issues related to infectious waste were also invited. Once the Agency has reviewed all of the public comments, the Agency plans to evaluate the need for additional information, to collect and examine such information, and to ultimately develop an effective Federal program addressing infectious waste. Upon evaluating the comments solicited in the Notice, the Agency will also reevaluate the status of the existing EPA guidance document on infectious waste.

TABLE OF CONTENTS

APPENDIX C

FACTORS DETERMINING THE TRUE COSTS OF SOLID WASTE MANAGEMENT TECHNOLOGIES

Page

1. INTRODUCTION C-1

2. COLLECTION AND TRANSPORTATION C-3
   a. Costs for Collecting and Hauling C-4
   b. Effects on Residents C-4

3. RECYCLING C-5
   a. Direct Costs C-5
   b. Revenues and Cost Offsets C-8

4. COMBUSTION C-12
   a. Direct Costs C-12
   b. Costs of Special Arrangements for Incinerators C-15
   c. Revenues and Cost Offsets C-17

5. PROCESSING C-17
   a. Direct Costs C-18
   b. Revenues and Cost Offsets C-19

6. LANDFILLS C-19
   a. Tipping Fees C-20
   b. Direct Costs C-21
   c. Revenue C-25
   d. Effects of Waste Quantity of Landfill Costs C-25

7. ACCOUNTING FORMAT C-27

8. SUMMARY C-30

LIST OF TABLES

APPENDIX C

Table		Page
C-1	Sample Calculation of Total Present Value of Landfill Costs	C-29

APPENDIX C

FACTORS DETERMINING THE TRUE COSTS OF SOLID WASTE MANAGEMENT TECHNOLOGIES

1. INTRODUCTION

Appendix C presents a rationale and an approach for local officials to identify true costs of the waste management options that they may be considering. Each of the solid waste management technologies discussed in this appendix has costs associated with its use. The appendix concludes that the costs faced by those who use waste management services should reflect the true costs of providing those services.

As with many other goods and services, the apparent costs of solid waste management, as reflected in tipping fees, charges on a county or local tax bill, or the cost of a sticker for access to the town landfill, rarely reflect the true costs of waste disposal. In general terms, communities simply do not consider all costs associated with landfilling when they set a price for disposal services. For example, subsidies for landfill operations that come from general revenues automatically lower the cost per ton that landfill users pay for disposal. Similarly, costs to close and monitor a landfill after it no longer receives waste are frequently ignored when tipping fees are set.

Markets for any goods or services operate according to the same rules: if the price is low, people will buy more. If the price for landfilling is held down by subsidies or by incomplete accounting of the true costs, individuals will buy more landfilling services (i.e., dispose of more solid waste) than they would if the price were higher. By the same logic, communities that are choosing from among waste management alternatives will rely too heavily on landfilling if its costs are not accurately presented.

To help local officials evaluate the true costs of solid waste management alternatives, this appendix describes the kinds of costs that should be included when analyzing options. Appendix C does not include worksheets to tally the costs of alternatives, and we do not present engineering or other cost estimates. The U.S. Environmental Protection Agency (EPA) is undertaking a separate effort to revise the "Decision Makers Guide" series for solid waste management. That document is scheduled for revision in 1989.[1]

In this appendix we discuss categories of costs that are part of each management option and describe in some detail those aspects of projects that are often left out of cost discussions because they are difficult to quantify or do not fit conveniently into categories of capital or operating costs. Near the end of Appendix C we will briefly discuss how these costs should enter calculations of total project costs.

Our convention for measuring costs is to focus on the incremental costs of various alternatives. If a town operates a landfill already, adopting a recycling program will result in new costs for recycling, but may also change expenditures for collection, transportation, and disposal. Local officials should consider all of these costs and offsets when evaluating changes to their solid waste management program. Equally important for this accounting approach, however, is the proper valuation of current activities. The correct increment on which to focus is the difference between the true costs of alternatives and the true costs of existing practices.

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[1] Existing materials from the late 1970's do provide accounting formats for costs. For example, the "Guides for Municipal Officials" series includes an accounting format for Resource Recovery Plant Implementation, EPA document SW-157.6.

Appendix C is organized around different components of solid waste management alternatives, beginning with collection and transportation and including recycling, combustion, processing, and landfilling.

2. COLLECTION AND TRANSPORTATION

A change in the waste management system for a community is likely to affect the collection and transportation of various materials. A curbside recycling program, for example, requires residents to sort materials at home and requires communities to provide special equipment to collect the recyclables, while still maintaining regular pickup of the rest of the waste stream. The community's equipment and labor needs would change and so would the cost of delivering service.

Local officials should be most concerned with identifying the incremental change in costs resulting from various options. The additional costs of special equipment to operate the program should be balanced against savings on existing routes. The remainder of this section presents categories of collecting and hauling costs to consider. This information is not meant as an exhaustive list of components or options, but instead illustrates the types of costs that should be included.

These are the same types of costs that communities should evaluate when assessing existing collection and transportation systems. If a community is considering whether or not to use private companies for its collection system, it should base the decision on the true costs of its current system.

a. Costs for Collecting and Hauling

Whether a locality provides collecting and hauling services itself or contracts the services out, the town will be the costs of a change in the routes and equipment required. Capital expenditures for a new program could include

- Collection vehicles
- Sorting centers (land, design, buildings, equipment)
- Transfer stations (land, design, buildings, equipment)
- Transfer (long-haul) vehicles

Each of these has operating and maintenance (O&M) costs associated with it and requires staff to operate it. Important O&M costs include fuel, insurance, maintenance, and repair. In addition to these direct costs, new facilities require siting approval and, in some cases, permitting, which can absorb a large amount of resources and which must all be attributed to the cost of the program. Siting costs are discussed in detail later.

b. Effect on Residents

Many recycling or processing programs require participation by residents. The direct cost associated with these programs is for separate storage bins for use at home. More difficult to measure, but more important to program success, is the requirement for additional time and effort by residents. This requirement may involve allocating space at home for extra storage, spending time sorting materials, or even hauling recyclables to designated pickup centers. While these costs cannot realistically be added to the bottom line of the balance sheet comparing alternatives, they are important to consider and will be a factor in determining the success or failure of the program.

3. RECYCLING

The "recycling" label covers a large range of programs in which materials are sorted and processed for reuse. While we do not focus on a particular type of program (e.g., curbside collection or multimaterial center recycling), the categories of costs apply across all programs. As with other options, decision makers should focus on incremental costs; if recyclers already exist, their operations could become part of the community's program.

a. Direct Costs

(1) Capital Costs

Costs for equipment and facilities can range from a very low share of the total costs (e.g., a parking lot recycling center consisting of a sign and a rolloff container) to a large share for a multimaterial center where materials may be sorted, cleaned, shredded, or baled. Typical cost components include

- Land (which should be based on the opportunity cost of the land; even if the town already owns the land or receives it at no cost, the land has a market value)
- Design and planning
- Site preparation
- Structures for administration, staff, equipment
- Storage equipment (buildings, rolloffs, barrels, bells or Igloos, etc.)
- Equipment for taking in materials (counting trays, scales, etc.)
- Processing equipment (trucks, forklifts, balers, shredders, grinders, cleaners)
- Other special equipment such as reverse vending machines or mobile units

(2) Operation and Maintenance Costs

O&M costs depend on the equipment, but generally include

- Maintenance
- Fuel and utilities
- Property taxes
- Rent
- Residual disposal costs
- Insurance
- Payments to customers (in some situations, centers may pass scrap values on to customers or may refund a deposit)
- Marketing costs
- Transportation costs
- Interest
- Administrative and overhead costs
- Return on investment (profit) if a private venture
- Wages and fringe benefits for administrative, management, and operations staff

(3) Other Costs

We have singled out several other costs for discussion. These costs are often difficult to predict in advance of a project but are part of the outlays attributable to its implementation.

Permitting, Siting, and Regulatory Compliance. Some regulatory compliance costs may be included in the equipment costs described earlier (e.g., structures must comply with local building codes). Of greater significance are the costs of shepherding a project through its initial phase. The process includes the presentation of plans and designs to local and State authorities for permission to locate a facility, complying with administrative and design requirements, and public hearings.

These steps can continue for an extended period and often require substantial legal and technical support, all of which will ultimately be part of the cost of the program.

This step may result in a requirement to perform additional studies, such as environmental impact analyses, analyses of traffic impact, and design modifications. In one state recently, a State-mandated recycling facility was denied a permit in a town unless it enclosed its storage areas with ivy-covered trellises.

Environmental Impacts. While siting and permitting requirements translate into additional development costs, other aspects of these programs impose costs that are not easily measured and are frequently ignored when choosing among alternatives. These costs are the result of the impact that these facilities have on the environment.

From the local perspective, the important consequences of these facilities include effects on traffic, noise levels, and potential pollution of air, surface water, and ground water. The kinds of effects are, however, difficult to quantify although they can be identified and discussed qualitatively as an important consequence of operating the recycling facilities.

Local planners can quantify these costs if the project includes provisions to mitigate some of the adverse effects. Costs for road improvements around the site and fences for noise and litter control will provide surrogate measures of the dollar value associated with those impacts by measuring avoidance costs.[3]

b. Revenues and Cost Offsets

The viability of a recycling operation depends on the revenue it will generate, but the range of revenue sources should extend beyond the cash flow from the sale of scrap material to savings (if any) attributable to removing recycled material from the waste stream.

(1) Revenues from Sales of Materials

While sale of materials is one of the most obvious sources of income for a recycling center, it is also one of the least reliable. Markets for recycled materials fluctuate constantly, making scrap revenue an uncertain base on which to fund a recycling program. Similarly, in a voluntary program, the supply of materials to the program is not guaranteed. These are the problems that plague operators of recycling programs and hinder their ability to raise capital to establish these programs. Local officials considering a recycling program, however, should include revenue from scrap materials in their cost calculation and should acknowledge uncertainty in the projections.

(2) Avoided Costs of Alternative Management

A recycling program will affect the costs of other aspects of the community's solid waste management program. The magnitude of the effect depends on the materials handled by the recycling program(s), the rate of participation in the program,and the method of collecting materials.

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[3] Because these are surrogate values, we cannot be sure that they accurately reflect the true value placed on the adverse impact. For example, the cost of fences and elaborate landscaping may far outweigh the adverse impact on passers-by of looking at a recycling facility. The same argument may also apply to environmental controls at landfills and incinerators. Measuring that adverse impact, however, would be an expensive and highly speculative exercise, so using avoided costs as a proxy is a reasonable approach.

An accurate accounting of the incremental costs or cost savings in other aspects of the program is extremely important in evaluating a recycling program or any alternative management approach. In each of the major sections of Appendix C, we discuss the most elements that local officials should include in their analysis of alternatives; the true costs of each alternative should be used for comparisons.

Collection and Hauling. The previous section of Appendix C discusses the correct components to include in determining the true costs of the existing collection and transportation program. To the extent that the recycling program replaces or decreases the volume sent through that system, some savings may accrue to the community.

A possible scenario for savings would be that a curbside program is established for several material types, and separate collection costs are calculated. Collecting the remaining solid waste may now be less expensive because routes can be lengthened and completed in less time. If the service is provided privately, the fees may decrease; if the community provides its own collection services, some of the same staff and equipment could be allocated to the curbside program.

From an accounting standpoint, however, it is important that only true savings be considered. If the reduction in the waste stream does not have an effect on the level of effort expended for collection of the remaining material, communities should not attribute any savings to the program. A collection program typically involves many fixed costs that communities must pay even if lower volumes are handled. For example, if only a small fraction of the waste stream is removed, the town would still have to operate the same number of vehicles and pay the same staff.

Combustion. A recycling program, depending on the materials recovered, could affect the costs of an existing incinerator. We will discuss these effects in general terms since, in the next section of this appendix, we will discuss in detail the component costs that should be included when determining the true costs of municipal waste combustion.

The first effect would be to decrease the volume of waste incinerated. If private operators charge the community on a per-ton basis, the town would realize savings from the recycling program. If, however, the plant produces energy, decreasing the waste throughput significantly could reduce the revenue produced from the sale of power.

If all of the costs are fixed (not sensitive to the volume incinerated), such as in cases where the community is contractually obligated to pay a set fee per year for the incinerator, no savings should be attributed to the recycling program.

A second effect of a recycling program is on the composition of the waste and, therefore, its Btu content. Some materials that could be taken out of the waste stream from recycling (paper and plastics in particular) have a relatively high Btu content. The resulting drop in heat content of the waste could adversely affect the performance of the incinerator and add costs to the community for supplemental fuel or reduce revenue from the sale of energy. Conversely, other low Btu content materials (such as yard waste, metal, and glass) that are removed by recycling could improve the performance of the incinerator. The net effect depends on the type and volume of materials removed for recycling.

Landfills. One of the most important factors in evaluating the true costs of a recycling program is avoided disposal costs. As with combustion costs, we will address these in more detail later in this appendix.

The most straightforward savings result from decreased tonnage placed in existing landfills. Depending on the landfill's ownership, the community may save on the per-ton fee it pays to a private operator, or it may save on variable costs if it operates its own landfill. As we will discuss below, the typical measure of landfill costs, tipping fees, may not reflect the true cost of landfilling and may, therefore, underestimate potential savings. Instead, the true costs of landfilling an additional ton of waste should be the basis for calculating the savings. For town-operated landfills, decreasing the landfilled volume will save on operating (variable) costs like labor, fuel, and daily cover but will not decrease fixed costs such as taxes, insurance, and interest in debt.

Another important savings that will grow as landfills become more difficult to site is the effect of recycling on capacity. If a landfill has 10 years of remaining life and the waste stream is cut by 10 percent, all costs associated with siting and developing a new landfill will be delayed by 1 year. A delay in expanding landfill capacity translates into real savings for two reasons. First, large expenditures of time and money are required early in the process of building a new landfill. Second, having a dollar today is more valuable than getting that dollar tomorrow because we discount future expenditures by the current rate of interest. As with any expenditure, even if we have the money now, we would prefer to delay the expenditure as long as the interest we receive on the money exceeds the rate of inflation. We will discuss the savings on future landfill capacity in more detail in the final section of this appendix.

4. COMBUSTION

Similar to the other waste management options, the capital and operating costs of incineration are straightforward to calculate, but several other aspects of the deal will substantially affect the economics of the project. We begin this section with an overview of the direct costs associated with an incineration project.

a. Direct Costs

(1) Capital Costs

The typical cost components for an incinerator include

- Land (based on its opportunity costs)
- Design and planning (development expenses will be discussed in more detail below)
- Site preparation
- The incinerator plant itself
- Equipment (front-end loaders, forklifts, etc.)
- Materials sorting/processing equipment (if any)
- Storage areas and equipment
- Emissions control equipment

(2) Operation and Maintenance Costs

- **Debt service**
- **Fee to operator**
- **Residuals disposal (using true costs of disposal as discussed below)**
- **Contingencies for incinerator downtime**
- **Insurance**
- **Taxes**
- **Rent**
- **Fuel, utilities, chemicals**
- **Repair and maintenance**
- **Administrative and overhead costs**
- **Environmental fees**
- **Monitoring costs**

- Return on investment (profit) if a private venture
- Wages and fringe benefits for administrative, management, and operations staff

(3) Other Costs

Preconstruction Costs. These costs include costs for complying with regulations, siting, permitting, and financing. As with recycling facilities, these costs can add significantly to the cost of a project and should be part of the total cost estimate. The cost estimates should also explicitly account for the current political problems associated with siting these plants.

The regulatory picture for municipal waste incinerators is particularly cloudy now, with several statutory and regulatory changes pending that could significantly change the economics of incinerators. Uncertainty over air emissions and ash is causing delays in permitting. Local officials must incorporate into their cost estimates the uncertainty regarding future legislation and regulations.

The siting and permitting issues for incinerators are technical and emotional given concerns about dioxin and other potentially hazardous materials emissions from incinerators. The development expenses associated with an incinerator include costs of designs, public hearings, zoning requests, and design revisions; these should all be part of the bottom line cost estimate for an incinerator.

Financing costs in addition to debt service are also a normal part of these projects. Firms that underwrite the debt used to finance these projects will receive fees for their services, which are part of total expenditures.

Environmental Impacts. The environmental impacts of incinerators include increased traffic flow near the incinerator, noise at the incinerator, air emissions, and potential ground-water contamination from ash in landfills. These costs are difficult to internalize into the costs of the project, especially because in some cases like ground-water contamination, the damage may never occur and, if it does, it could be insignificant or could contaminate a major water supply.

We will discuss the difficulty of internalizing these costs several places in this appendix. As with other waste management alternatives, part of the cost can be captured by the proxy of prevention costs. Installing an elaborate air pollution control system on an incinerator will help ensure that damages resulting from air emissions will be negligible. This process does not ensure that the expenditure will be commensurate with the potential damage (i.e., that the controls are justified on a benefit-cost basis), but it provides some indictor of the damage.

Another proxy for the value of damages that might occur is the cost of insurance (if it is available) against accidents or for liability. Ideally, the price of insurance reflects the probability of damage occurring and the extent of the damage plus compensation for the insurer that bears the risk. If the insurance company's risk assessment is accurate, the premiums charged will channel the costs through to the facility operator. In some cases, however, operators find insurance unavailable or prohibitively expensive. In these cases the facility owner (and ultimately the community's citizens) will bear all the risk of potential damage. Finally, as discussed in the landfill section of the appendix, landfilling costs for ash or noncombustibles should also include estimates of potential damage.

b. Costs of Special Arrangements for Incinerators

Incinerator vendors always tailor their proposals to the needs of the specific community. The nature of the deals struck between vendors and communities is a major factor determining the viability of a combustion option for a community. These deals may cover assumption of risks and waste supply guarantees. Arrangements that affect revenues are discussed later.

(1) Risk Premiums

Some communities may be extremely risk averse: they do not want to bear financial responsibility for changes in the parameters of the deal on their incinerators.[9] Examples of events that would alter the terms of the deal are increases in per-ton fees because of regulatory changes or tax law changes. Vendors may be willing to offer assurance to communities that the terms will not change, but the vendor must be compensated for assuming the risk. The cost of buying a risk-free agreement with a vendor will clearly be much higher than the cost of an arrangement where the community will bear the burden of a large increase in costs.

From the standpoint of computing true costs, the value of such an "insurance policy" from a vendor is very useful because it represents an informed assessment of the probability and magnitude of possible cost increases and captures those costs in a flat fee or additional cost per ton of waste handled at the incinerator. Whether or not localities choose to purchase security at these prices is up to the individual decision makers, but if the community bears the risk itself, the expected cost of these risks should be included in the cost of the alternative.

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[9] Similarly, the individuals who provide financing for these projects must be insulated from some of the risk. Otherwise, the investment will be too speculative to attract investors without offering much higher interest rates (which would increase the town's debt service substantially).

(2) Guaranteeing Waste Supply

Because an incinerator has a lot of fixed costs associated with it, the facility should always operate near its designed capacity in order to spread those fixed costs over a larger quantity of waste and thereby keep costs under control. At the same time, larger facilities can achieve greater economies of scale so that if the same technology is used at two plants, the larger plant will have a lower cost per ton. An incinerator that handles waste from several jurisdictions, for example, can provide these lower unit costs. Communities are understandably hesitant to commit to a plant that has a design capacity beyond what the community can guarantee, because they fear that the waste will not be available and that the community will be unable to recover its investment.

To address this risk, vendors may assume the risk for obtaining additional waste, which will allow the town to take advantage of the economies of scale without bearing the risk of guaranteeing a flow of waste above the volume of residential waste in the community. The community would have to pay for this assumption of risk by the vendor, and the cost is part of the bottom line for the alternative.

We have provided several examples of additional costs that are part of the true costs of choosing combustion as a waste management alternative. These costs are often not considered until after decisions are made to proceed with a given alternative. Local officials should be aware of these costs and consider them at the initial stages of their evaluation of alternatives.

c. Revenues and Cost Offsets

If materials (glass, metals) are separated from the waste stream at the incinerator, the operation should generate revenue from the sale of those materials. Also if the incinerator is designed to produce energy (the heat is used to fire a boiler as nearby facilities may use the steam or the steam can be used to generate electricity), the revenue for the power should be credited against total costs.

Localities may choose to participate with the vendor in selling capacity to other communities or commercial markets. Earlier we described a situation where the community incurs additional cost to ensure itself against some future cost increases or interruptions in the flow of waste. Alternatively, a community could choose to build capacity beyond its own residential waste demands and then share in the proceeds of the larger plant (e.g., share energy revenue and receive a return on its investment).

Finally, waste combustion will significantly affect the volume and type of waste landfilled. Communities should balance out savings on operating costs at existing landfills and savings from delayed construction of replacement landfills with any incremental costs incurred as the result of landfilling incinerator ash. For example, communities may find that legislative changes require a different type of landfill or at least different management practices for incinerator ash. The attractiveness of the combustion option will likely hinge on the balance between disposal cost savings and incinerator costs.

5. PROCESSING

This category includes processes that reduce the volume of waste disposed of and, in the case of composting, that turn the waste into a product which can be reused. These processes are shredding, baling, and composting.

a. Direct Costs

Equipment and facilities' costs will include

- Land (valued according to its opportunity cost)
- Design and planning
- Site preparation
- Structures for administration, staff, and equipment
- Storage area (buildings, environmental controls)
- Processing equipment (trucks, forklifts, sorters, shredders, balers)
- Other special equipment (settling basin and wastewater treatment for runoff, packaging or loading equipment for composted material)

Operating costs include

- Maintenance and repair
- Fuel and utilities
- Property taxes
- Rent
- Residual disposal costs
- Insurance
- Interest
- Administrative and overhead costs
- Return on investment (profit) if a private venture
- Wages and fringes for all employees

Other costs for permitting, siting, regulatory compliance, and environmental impacts are quite similar to those discussed for recycling centers and incinerators. The siting and permitting stages of the project will involve the same problems and expenses. Costs for mitigating environmental impact can be shown by including the project costs for equipment or labor that will prevent adverse affects such as runoff controls, wastewater treatment, and litter containment fences.

b. Revenues and Cost Offsets

The major offset to costs of these programs are savings on alternative management costs. Removing material from the waste stream or increasing the density of waste entering a landfill saves on the current variable costs of landfilling and helps delay future expenditures for new landfill capacity or for other waste management alternatives.

In the case of combustion, processing the waste may be part of the incineration project (as for refuse-derived fuel projects), but processes like composting for some waste materials may actually improve the performance of existing incinerators by removing low-Btu content waste from the waste stream.

Finally, composting may result in a product with market value as a fertilizer or soil additive.

6. LANDFILLS

Because landfilling is the dominant management method for municipal solid waste, proper measurement of the costs of landfilling is particularly important. Not only do landfills provide the standard of costs against which alternatives are measured, but alternatives may result in avoided landfilling costs. An accurate accounting of avoided landfill costs will allow for better decisions about whether an alternative is justified on economic grounds.

We will draw distinctions in several cases between existing landfills and new landfills. While the principles behind the measurement of their costs are the same programs that affect the flow of waste to existing landfills change the operating costs for the existing unit. At the same time, the rate at which existing units are filled affects the timing of new units. Since future expenditures have a lower present value than current expenditures, alternative waste management strategies that delay replacement landfill also save money.[*]

The following section discusses tipping fees, the distinction between tipping fees and actual costs, the various costs of landfilling, and the revenues and cost offsets.

a. Tipping Fees

From the standpoint of measuring true costs of landfilling, the worst mistake is to rely on published tipping fees as an indication of the true costs of landfilling. A detailed analysis of tipping fees vs. actual costs is found in Chapter 3 of the supporting document. To summarize that discussion, many cost factors that we will discuss below are not included when tipping fees are calculated. Often communities calculate tipping fees to cover the operating costs of a landfill without regard to amortization of capital equipment, value of the land, costs of closure, post-closure care, and potential remedial action at the

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[*] Present value is an important accounting concept in evaluating alternative projects. Present value is the current dollar value of a stream of future payments. Because, as discussed earlier, a dollar today is worth more than a dollar tomorrow, future payments are discounted back to current dollars using the appropriate interest rate. A general formula for present value is

$$\sum_{i=0}^{n} Cf_i * [1 / (1 + r)^i]$$

where Cf is cash flow, i is the year in which the cash flow occurs, n is the last year of the cash flow, and r is the interest rate. The formula describes a sum of discounted cash flows over future time periods. More detail on present values can be found in finance textbooks. Also, calculators and financial software packages such as Lotus 1-2-3 contain present-value functions that can calculate present values.

landfill. Beyond the issue of which costs are included in tipping fees, the fees are often subsidized by local budgets so that the true cost of landfilling a ton of waste is much higher than the per-ton cost that is quoted.

Private landfill owners are more likely to include these costs in tipping fees because the fees charged provide their major source of revenue. Unlike local governments, private owners cannot tap into general revenues to subsidize the cost of running a landfill.

b. Direct Costs

(1) Initial Capital Costs

Costs for equipment and construction dominate the costs for a landfill and, with more stringent landfill regulations on the horizon, will become an even greater fraction of the total cost. The magnitude of these fixed costs explain the economies of scale observed in landfill construction. As with incinerators, the cost per ton of waste disposed of decreases as the size of the landfill increases. These scale economies explain why there is a strong cost incentive for regional arrangements that allow management of waste from many jurisdictions in one large unit.

Land costs, identified as an important component for recycling and other alternatives, are even more important for landfills because landfills take up more space. The land chosen for a landfill is often already owned by the community and may, therefore, be considered "free" when used for a landfill. From an economic standpoint, however, the land has a value equal to the price it would fetch in the current market. If the land could be sold to developers for $20,000 per acre, the town should include that cost in determining the true cost of a new landfill. Similarly for existing units, a community should attribute to the land a value consistent with an alternate use. If the land were not covered with a landfill, it could, for example, be sold or used as a recreation area. In either case, the land's value in an alternate use should be added to costs.

Other costs include

- Design and planning (discussed in more detail below)
- Site preparation
- Excavation
- Containment systems
  - Surface-water controls
  - Ground-water controls (liners, leachate collection)
  - Air emission controls
- Monitoring systems
  - Ground water
  - Surface water
  - Gas
- Receiving equipment (scales, rolloffs, parking)
- Equipment (trucks, compactors, bulldozers)

(2) Operation and Maintenance Costs

- Debt service
- Fee to operator (if privately operated)
- Fuel and utilities
- Monitoring and testing
- Repair and maintenance of equipment, liners, etc.
- Daily cover
- Leachate management (collection and onsite treatment, recirculation, offsite treatment)
- Licenses and environmental fees
- Insurance
- Administrative and overhead costs
- Return on investment (profit) if privately operated
- Wages and fringes for all staff

(3) Closure and Post-Closure Costs

Unlike the other waste management options we have discussed, landfills require significant expenditures after their active life is completed. While current practices typically include covering a landfill and maintaining it, the revised criteria will strengthen those requirements.

The major capital cost at closure is for the cover and its installation. After the unit is closed, however, costs continue for monitoring, leachate management, cover repair, and inspections. The costs of these activities must be predicted and planned for when determining how to set tipping fees. Once waste is no longer disposed of at the unit, it is too late to recover these costs, so they should be built into the true cost of the landfill during its operating life.

(4) Other Costs

Permitting, Siting, and Regulatory Compliance. Like incinerators, transfer stations, and recycling facilities, new landfills face stiff siting opposition. The cost of designing, dealing with public comments, evaluating alternative sites, and redesigning landfills must all be part of the cost of new landfills. Another important dimension to siting and permitting costs is the cost of delays brought about by protracted legal and political battles. The community may have capital tied up in the new project and cannot use it for other purposes. Also, in an inflationary environment, the costs continue to climb while construction is delayed.

Regulatory compliance costs are already part of the capital and operating costs listed above. Included with these costs for monitoring and liners should be environmental site assessments, traffic studies, hydrogeological assessment, and permitting fees. To the extent that regulations affect existing landfills, landfill operators should make those incremental compliance costs part of their cost structure and should reflect the higher costs in higher tipping fees.

Compensating Landfill Neighbors. Often the result of a battle over siting results in compromises between the landfill builder and the landfill's neighbors. These compromises could take the form of infrastructure improvements (roads, bridges, rail lines); protection for property values; and fee subsidies. The site developers may need to guarantee that property values for the land around the landfill will not be adversely affected. The community could purchase surrounding land outright or guarantee its value. The community developing the landfill could also allow customers near the landfill to dispose of their wastes at a lower cost, although this conflicts with an overall strategy to make landfilling costs reflect true costs.

Environmental Impacts. As with other alternatives, communities may include costs of environmental impacts in their true cost estimates by estimating costs to prevent environmental damage. Adding more elaborate containment systems to the landfill is one such approach. Even with elaborate designs and conscientious operation, some damage may still occur and landfill owners should plan for those contingencies. We should also repeat that it is not desirable in every case to impose the most stringent design criteria on every landfill, because the cost of prevention may far exceed the potential damage it prevents.

One of the most significant liabilities faced by landfill owners is if the landfill releases contaminants to nearby ground water or surface water, or if explosive gas escapes from the unit and damages nearby structures. The true cost of the landfill should reflect the magnitude of the costs required to clean up spills or mitigate their effects, but clearly these incidents vary in their severity and may never occur at all. Landfill operators with insurance to cover these events already have as part of their costs some allowance for remedial action costs.

Another approach for measuring avoided costs of environmental impact is to include the cost of a wider search for better landfill sites. Finding a site with characteristics that will minimize environmental impacts (located in native clay, dry climates, etc.) may mean higher siting costs and higher transportation costs over time. These expenses may be offset, however, by lower design costs and lower risk of releases at the better site.

The proposed landfill criteria contain provisions that will require owners to have some mechanism for ensuring that they can cover the costs of closure and, once corrective actions are triggered, the cost of cleanup. These regulatory initiatives help force communities to consider future costs in their current fee structure and, thereby, to charge landfilling fees that reflect true costs.

c. Revenue

Other than tipping fees, the only major revenue that a landfill can provide is from energy produced from methane gas. Methane results from the decomposition of organic material in the landfill, and in some large landfills the volume of gas produced is sufficient to generate power. In these cases, the revenue will not begin until well into the landfill's operating life and will continue several years after the unit is closed.

In addition, the land on which the unit is located will have some value after landfilling activity is complete. Using the land for parks or other purposes carries some value that communities should factor into the bottom line.

d. Effects of Waste Quantity on Landfill Costs

All of the waste management alternatives discussed in this appendix will affect the volume of waste landfilled. In each case, we have argued that the cost analysis of each alternative should include the incremental costs and savings from landfilling. In most cases the landfilled volume will decrease, resulting in savings for both existing and new landfills.

(1) Existing Units

Each ton of waste kept out of an existing unit will save on variable operating costs such as fuel, labor costs, and equipment costs. Certain other costs such as taxes, insurance, rent, and selected equipment remain fixed regardless of how much less waste enters the landfill. The correct measure of savings from decreasing the waste flow is the volume of waste multiplied by the variable costs per ton. Operators must still pay for their fixed costs, regardless of the amount of waste entering the unit.

(2) New Units

Every ton of solid waste disposed of today brings the need for a replacement landfill that much closer. Given the statistics on landfills' remaining lives cited in Chapter 3 of the supporting document, many replacement landfills will be built in the next 5 to 10 years. The cost for a new landfill is climbing steadily because of more stringent regulations, local opposition, and the trend toward reflecting true costs in the price of landfilling (as advocated in this appendix). With a large, future replacement cost, communities have strong incentives to prolong the life of existing units and forestall the higher costs of a new unit. Each year that a replacement unit is delayed translates into a cost savings because the discounted value of the new landfill (the future costs adjusted to present-value terms based on the underlying interest rate) goes down.

If a community can estimate the present value of its replacement landfill, it can also estimate the incremental savings of delaying the startup date by a certain amount. Local officials should take that savings into account when evaluating recycling, combustion, and waste processing options.

7. ACCOUNTING FORMAT

While we have not developed this appendix to the point of providing detailed inputs for cost calculations, we have discussed several cost categories that are not typically part of an engineering cost estimate. For reference purposes we will briefly discuss how these costs should enter the calculation of project costs.

The first point to make is that all costs related to the project, but incurred before the acceptance of waste at any management facility, should be attributed to the project. Costs of finding a site, hiring consultants, and defending proposals in public hearings should be summed and carried into the stage of the project when it begins to accept waste (i.e., generates some revenue). If interest costs are incurred because the initial funds were borrowed, these should be added. These costs are the first component of the total present value of costs.

The second part of the present value of costs are expenses incurred to build and operate the facility. All costs including land, subsidies for neighboring communities, monitoring, and amortization of equipment should be added. Costs in future years should be discounted back to the present using appropriate interest and inflation rates.

The final part of the estimate is for costs incurred after waste is no longer accepted at the unit. These costs include monitoring, corrective actions to clean up releases, decontamination, and site reclamation. Again, since these costs are in future years, they should be discounted back to the present. Costs that are uncertain such as costs to clean up releases may be included in expected costs (i.e., the cost to correct the release multiplied by the probability that such a release will occur).

When all costs are discounted to a single present value, that value is the total present value of costs for the life of the facility. Figure C-1 provides a hypothetical example of a stream of costs over the development, operation, and closure of a new landfill. The costs are for illustration purposes only and present values were computed as described in Footnote 4.

Revenues or savings from the facility should be combined on a present-value basis as well. Revenues from scrap sales or energy sales should be projected into the future and discounted back to current dollars. Uncertainties in prices can be captured by using a range of values and predicting revenues under several different scenarios.

The annual savings on existing landfills should be projected into the future (making sure that the true costs of operating the landfill at a lower level of throughput are included) and discounted to the present. Finally, the savings should include an estimate of delays in constructing a new landfill or other alternative. Operators should estimate the total present value of costs for a replacement unit, calculate the number of years that the facility will be delayed, and compute the savings attributable to delaying the expenditure for those years.

The total present value of savings or revenues should then be combined with the total present value of costs to compute one present value. This total cost of the project must be allocated to the waste expected over the lifetime of the unit. The

TABLE C-1

SAMPLE CALCULATION OF
TOTAL PRESENT VALUE OF LANDFILL COSTS

	Year	Cost in Current Dollars	Present Value
(Preconstruction)	0	$ 300,000	$ 300,000
	1	300,000	280,374
	2	300,000	262,032
(Construction)	3	5,000,000	4,081,489
(Operation Begins)	4	250,000	190,724
	5	250,000	178,247
	6	250,000	166,586
	7	250,000	155,687
	8	250,000	145,502
	9	250,000	135,983
	10	250,000	127,087
	11	250,000	118,773
	12	250,000	111,003
	13	250,000	103,741
(Closure)	14	2,500,000	969,543
(Post-Closure)	15	25,000	9,061
	16	25,000	8,468
	17	25,000	7,914
	18	25,000	7,397
	19	25,000	6,913
	20	25,000	6,460
	21	25,000	6,038
	22	25,000	5,643
	23	25,000	5,274
	24	25,000	4,929
	25	25,000	4,606
	26	25,000	4,305
	27	25,000	4,023
	28	25,000	3,760
	29	25,000	3,514
Total		$11,275,000	$7,415,077

Note: Costs and the lifespan of this landfill are hypothetical. A 7 percent interest rate was chosen at random. The present value equation is shown in Footnote 4.

procedure for calculating the total cost per ton, for example, is to bring the present value of the total cost of the project into the first year that waste is received. The present value should then be annualized over the years of operation.[*] The annualized cost divided by the tons of material accepted each year will provide a total cost per ton estimate for the project. The price charged for use of the facility should cover this total cost.

8. SUMMARY

The costs of waste management alternatives provide the basic information on which communities base decisions about how to handle their solid waste. Communities should rely on cost estimates that are as comprehensive as possible for each alternative that they consider. In addition to costs provided by consulting engineers for equipment and operations,s communities should always consider

- Preconstruction costs to permit and site facilities, given the range of applications, permits, studies, legal fees, public hearings, and plan revisions that are likely
- Opportunity costs of land
- Costs to mitigate environmental effects and, where these surrogate values for environmental damage are not appropriate, a qualitative consideration of the effects of each alternative
- Costs of special arrangements with neighboring communities or vendors of equipment

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[*] The annualization factor is multiplied by the present value to give the cost in each year of operation. The factor is where

$$[r * (1 + r)^n]/[(1 + r)^n - 1]$$

r is the interest rate and n is the number of years the facility will accept waste.

- Liability costs for future damages, either as insurance premiums or costs of some financial instrument to self-insure

On the revenue side

- Revenues from scrap sales, energy production, or other products from waste processing
- Savings on current collection and handling
- Savings on operating costs at existing landfills
- Savings from delaying replacement landfills

Considering each of these components may add time and effort to the evaluation process, but the result of using a true cost basis for comparing alternatives will save resources in the long run by ensuring that a community has chosen the alternatives with the lowest costs.